FINAL REPORT

Economic Evaluation of the Open Space Credit

Prepared for

Santa Clara Valley
Water District

5750 Almaden Expressway
San Jose, CA 95118

August 15, 2013

Prepared by

Duncan MacEwan, Ph.D.
Richard Howitt, Ph.D.

eraeconomics
environment • resources • agriculture

Executive Summary

Santa Clara Valley Water District (the District) contracted with ERA Economics to provide an independent and quantitative analysis of the Open Space Credit and changes to the agricultural groundwater charge in Santa Clara County. The study consists of three parts: (i) an analysis of the value of agricultural open space, (ii) an analysis of important ecosystem service values provided by agriculture, and (iii) an economic analysis of the direct costs to growers resulting from changes in the agricultural groundwater charge. The information and findings in this report can be used by the District staff, Board of Directors, stakeholders and the community to make informed decisions concerning changes to the Open Space Credit.

Since 1980 harvested agricultural acreage in Santa Clara County has decreased from a peak of 44,000 acres in 1987 to 18,500 acres in 2011. The decline in Santa Clara County agriculture has been driven by a number of factors including increased competition and market-driven production shifts to other regions. Despite the decline in total acreage, increased productivity and real crop prices over the same time period have kept gross crop revenues constant in real terms. Average gross crop revenue per acre has increased from a low of $2,100 per acre in 1990 to $4,500 per acre in 2011 in real terms.

The study finds that agriculture provides positive value as open space and from most ecosystem services. Increasing the agricultural groundwater charge would impose direct costs to growers but most of these costs are a result of higher water rates, not from land fallowing. The study finds that increasing the agricultural groundwater charge to 10 percent of municipal and industrial (M&I) rates will result in less than 1 percent decrease in total harvested acres in Santa Clara County.

Agricultural open space provides value to the community. The analysis of the value of agricultural open space involved a literature review and meta-analysis of relevant studies conducted in other regions. Agricultural open space is not traded in a market so its value is inferred by statistical analysis of nearby home values. Key findings include:

- Cropland open space increases home values within 0.25 mile by 2.2 percent, on average.
- Rangeland, native vegetation and conservation easement open spaces increase home values within 0.25 mile by 2.56 percent, on average.
- Intensive agriculture such as mushroom farms and livestock operations decrease home values within 0.33 mile by 6.4 percent, on average.

Agriculture provides services to the ecosystem which provide value to the county and District. The analysis of the value of ecosystem services provided by agriculture involved a literature review and meta-analysis of relevant studies conducted in other regions. There are many types of ecosystem services and most are not traded in markets. The analysis included the seven following ecosystem services commonly associated with agriculture: flood control, groundwater recharge, water quality, pollination, habitat, biodiversity and nitrogen regulation. Key findings based on a meta-analysis include:

- The value of flood control provided by agriculture is estimated at between $42 and $86 per acre. This figure is likely to be higher in Santa Clara County where flood events have a higher cost than the areas evaluated in the reference studies.
- The value of groundwater recharge provided by agriculture is estimated at between $135.30 and $167.28 per acre based on a soil-water balance developed for Santa Clara County.

The analysis of the direct costs to growers from changes in the agricultural groundwater charge involved comprehensive data collection and the development of an economic model of agricultural production in Santa Clara County. The model was used to estimate the responses of growers to incremental changes in the agricultural groundwater charge, and the corresponding effect on crop mix, land fallowing, and profits. Two scenarios were evaluated relative to baseline conditions: agricultural groundwater charge increasing to 10 percent or 25 percent of M&I rates over a 10 year phase-in period from fiscal years 2015 to 2024. The incremental cost is the annual cost in each year of phase-in and the present value of the total cost is the sum of the incremental costs in current dollars. Key findings include:

- When the agricultural groundwater charge increases to 10 percent of M&I rates over 10 years the incremental cost per year increases from $26,800 in FY 2015 to $465,000 in FY 2024. The present value of the total cost to growers is estimated to be $6.96 million. Total harvested area declines by 17 acres, less than 1 percent.
- When the agricultural groundwater charge increases to 25 percent of M&I rates over 10 years the incremental cost per year increases from $80,800 in FY 2015 to $2.51 million in FY 2024. The present value of the total cost to growers is estimated to be $35.91 million. Total harvested area declines by 549 acres, less than 3 percent.

Contents

Executive Summary 2
Contents 4
List of Figures 6
List of Tables 6

1. Introduction 8
1.1 Structure of the Report 8

2. Problem Statement 9

3. Overview of the Approach 10

4. Santa Clara County 11
4.1 Agricultural Production 11
4.2 Agricultural Employment 13
4.3 Agricultural Revenues 14

5. The Value of Agricultural Open Space 16
5.1 The Value of Open Space in Santa Clara County 17
5.1.1. Results 17
5.1.2. Example Application 18

6. The Value of Ecosystem Services 20
6.1 Meta-analysis of the Value of Ecosystem Services in Santa Clara County 20
6.1.1. Results 21

7. Analysis of the Agricultural Groundwater Charge 23
7.1. Groundwater Charge Scenarios 23
7.2. Santa Clara County Agricultural Production Model 23
7.3. Groundwater Costs as a Percent of Variable Costs 24
7.4. Direct Costs to Growers 25
7.4.1. Agricultural Groundwater Charges at 10 Percent of M&I Rates 26
7.4.2. Agricultural Groundwater Charges at 25 Percent of M&I Rates 26
7.5. Changes in Irrigated Acres 27
7.6. Costs to the County Economy 28

8. Summary of Findings 29

Technical Appendix A: Value of Open Space 30
A.1. The Value of Open Space in Santa Clara County 30
A.1.1 An Overview of the Value of Open Space 31
A.1.2. Positive and Negative Amenities 32
A.2. Meta-Analysis of the Value of Open Space 33
A.2.1. Summary of Results 34
A.2.2. Example Application 35
A.3. Conclusion 36
A.4. Relevant Studies Reviewed 36

Technical Appendix B: Ecosystem Service Value 37
B.1. Ecosystem Services 37

B.1.1. Methods for Estimating the Value of Ecosystem Services 38
B.2. Ecosystem Services Related to Agriculture 39
B.3. Meta-Analysis of Ecosystem Service Value 39
B.3.1. Summary of Meta-Analysis Results 40
B.4. Santa Clara County Framework 42
B.4.1. Flood Control 42
B.4.2. Groundwater Recharge 42
B.4.3. Summary 44
B.5. Conclusion 44
B.6. Relevant Studies Reviewed 45

Technical Appendix C: Model Documentation 47
C.1. Problem Overview 47
C.2. Santa Clara County Agricultural Model Objectives 47
C.3. Santa Clara County Model Overview 48
C.3.1. Model Calibration 49
C.3.2. Model Validation 50
C.4. Santa Clara County Model Components 50
C.4.1. Crops 50
C.4.2. Geographic Regions 51
C.4.3. Land Use Data 52
C.4.4. Acreage Response Elasticities 53
C.4.5. Crop Prices and Yields 53
C.4.6. Other Input Costs 54
C.4.7. Water Use, Availability and Costs 54
C.5. Using the Model 54
C.5.1. Data Input File 55
C.5.2. Model Program File 55
C.5.3. Solver Options File 55
C.5.4. Output File 55
C.6. Relevant Studies Reviewed 55

List of Figures

Figure 1. Total Harvested Acres in Santa Clara County, 1980 – 2011 12
Figure 2. Total Farm Jobs in Santa Clara County, 1990 - 2011 13
Figure 3. Gross Agricultural Crop Revenue in Santa Clara County, 1980 - 2011 (2012 Dollars) 14
Figure 4. Gross Agricultural Crop Revenue per acre in Santa Clara County, 1980 - 2011 (2012 Dollars) 15
Figure 5. Farm Monitoring and Mapping Program (FMMP) Aggregate Land Use, 2010, and Agriculture-Urban Interface 16
Figure A1. Farm Monitoring and Mapping Program (FMMP) Aggregate Land Use, 2010, and Agriculture-Urban Interface 31
Figure C1. Santa Clara County Model Regions 52

List of Tables

Table 1. Farm Mapping and Monitoring Program 2010 Reported Santa Clara County Land Use 11
Table 2. Harvested Acres in Santa Clara County, 2001 - 2011 12
Table 3. Summary of Open Space Value 18
Table 4. Value of Open Space Example 18
Table 5. Meta-Analysis of the Total Value of Ecosystem Services Provided by Agriculture 22
Table 6. Groundwater Recharge Ecosystem Service Value in Santa Clara County 22
Table 7. Agricultural Groundwater Charge ($/af) by Fiscal Year 23
Table 8. Santa Clara County Model Crop Acreage, 2010-2011 Average 24
Table 9. Agricultural Groundwater Charge as a Percent of Variable Production Costs, Weighted Average by Fiscal Year 25
Table 10. Total Groundwater Cost as a Percent of Variable Production Costs, Weighted Average by Fiscal Year 25
Table 11. Direct Cost to Growers, by Fiscal Year (dollars in thousands) for 10 percent of M&I 26
Table 12. Direct Cost to Growers, by Fiscal Year (dollars in thousands) for 25 percent of M&I 27
Table 13. Fallow Acres due to Increased Groundwater Charge 27
Table A1. Summary of Open Space Value 35
Table A2. Value of Open Space Example 35
Table B1. Meta-Analysis of the Total Value of Ecosystem Services Provided by Agriculture 41
Table B2. Land and Water Use Summary Data 43
Table B3. 1990-2003 Average Monthly Rainfall at Gilroy, California (inches) 43
Table B4. Groundwater Recharge Ecosystem Service Value in Santa Clara County 44
Table C1. Santa Clara County Model Crop Groups 51
Table C2. Santa Clara County Model Crop Acreage, 2010-2011 Average 53

1. Introduction

Santa Clara Valley Water District (the District) contracted with ERA Economics to provide an independent and quantitative analysis of the Open Space Credit and changes to the agricultural groundwater charge in Santa Clara County. The Open Space Credit exists to encourage agricultural lands in Santa Clara County.

Increasing the agricultural groundwater charge would decrease the Open Space Credit and potentially allow the District to fund other activities. This study estimates the value of agriculture and the economic costs of increasing the agricultural groundwater charge in order to inform future policy discussion. The study does not include a benefit-cost analysis for Open Space Credit funding. To inform future discussion, the study consists of three parts: (i) an analysis of the value of agricultural open space, (ii) an analysis of important ecosystem service values provided by agriculture, and (iii) an economic analysis of the direct costs to growers resulting from changes in the agricultural groundwater charge.

Santa Clara County has experienced a shift in land use from agriculture to urban development, primarily in North County. Since 1980 harvested agricultural acreage in Santa Clara County has decreased from a peak of 44,000 acres in 1987 to 18,500 acres in 2011. The decline in Santa Clara County agriculture has been driven by a number of factors including increased competition and market-driven production shifts to other regions. Despite a decline in total acreage, increased productivity and real crop prices over the same time period have kept gross crop revenues constant in real terms. Gross crop revenue per acre has increased from a low of $2,100 per acre in 1990 to $4,500 per acre in 2011 in real terms. Santa Clara County acreage has been contracting for some time but the gross value per acre has been steadily increasing.

To estimate the economic impacts of changes in the agricultural groundwater charge this study holds all other factors constant. Possible costs to agriculture such as increasing electricity rates and labor costs are not considered in the analysis. Possible benefits to agriculture such as increasing real crop prices and productivity are also not considered in the analysis. This is necessary in order to isolate the effects of increases in the agricultural groundwater charge on the agricultural community.

The information and findings in this report can be used by the District staff, Board of Directors, stakeholders and the community to make informed decisions concerning changes to the Open Space Credit.

1.1 Structure of the Report

The main text of this report provides a summary and overview of the economic evaluation of the Open Space Credit. The interested reader can find details and further documentation in three supporting technical appendices. The main text and each of the appendices can each be read as stand-alone documents.

Section 2 provides the problem statement and section 3 provides an overview of the quantitative approach. Section 4 summarizes important agricultural statistics for Santa Clara County and includes a discussion of important trends underlying the historical decline in crop acreage. Section 4 additionally includes summary statistics for the value of agricultural production in Santa Clara County. Sections 5 and 6 summarize the value of agriculture beyond direct crop production, including the value of open space and the value of ecosystem services provided by agriculture. Section 7 summarizes the economic impact analysis of increases in the agricultural groundwater charge. Technical appendices A, B and C provide additional detail and references for sections 5, 6 and 7, respectively.

2. Problem Statement

The Open Space Credit takes the form of a subsidy to agricultural groundwater users such that currently agricultural producers pay 3 and 6 percent of the municipal and industrial (M&I) rate in North County and South County, respectively. Section 26.7(a)(3)(D) of the District Act limits the agricultural groundwater charge to an amount no greater than 25 percent of the M&I groundwater charge. Resolution 99-21 sets the agricultural groundwater charge at no more than 10 percent of M&I rates. The Open Space Credit is funded by non-rate related revenues from ad valorem property taxes in the General, Water Utility, and Watershed Stream Stewardship Funds. Increasing the agricultural groundwater charge would decrease the Open Space Credit and potentially allow for the reallocation of property tax revenues to fund other District activities. However, higher agricultural groundwater charges may affect the viability of the agricultural economy in Santa Clara County and, in turn, the preservation of open space for which the Open Space Credit was first established. The District commissioned this study in order to better understand short and long-term impacts of higher agricultural groundwater charges.

The District has requested a study that provides an assessment of the value of agriculture and the economic impacts of changes to the agricultural groundwater charge. The study includes an estimate of the value of agriculture as open space and for ecosystem services. The economic impact analysis includes two alternative scenarios where agricultural groundwater charges are increased to either 10 percent or 25 percent of M&I water rates by fiscal year 2024. The scenarios include a 10 year phase-in period starting in fiscal year 2015. Economic impacts are estimated relative to baseline agricultural groundwater charges projected by the District over the same 10 year period.

This study provides a basis for understanding the value of agricultural land in terms of open space and ecosystem services, and the direct costs to growers from changing the agricultural groundwater charge. This study does not estimate the total economic costs to the Santa Clara County economy from changes in the agricultural groundwater charge. The study does not provide benefit-cost analysis of shifting property tax revenues from the Open Space Credit to other district activities. However the results of this analysis represent the starting point for county-wide impact and benefit-cost analyses.

3. Overview of the Approach

The first part of the study estimates the value of agricultural open space and the value of ecosystem services. Open space and ecosystem service values for Santa Clara County agriculture are established from a literature review of studies conducted in different regions with results that are applicable to Santa Clara County. A set of selection criteria were applied to identify a subset of relevant studies and a smaller subset of these studies were selected to include in a meta-analysis to estimate the values in Santa Clara County.

The second part of the study estimates the direct cost to growers, and underlying changes in the crop mix and total irrigated acreage, from to higher agricultural groundwater charges. Given that the agricultural groundwater charges considered in this analysis are in the range of 1–5[1] percent of variable production costs, on average, an accounting approach based on average crop budgets would not reflect the subtle changes in costs and acreages implied by relatively small changes in the agricultural groundwater charge. An economic model of agricultural production in Santa Clara County was constructed for the study. This involved data collection on the different types of crops, the groundwater basins in which they were grown, and the revenues and costs associated with producing each crop. In addition, the relative responsiveness of farmers to changes in costs for different crops was based on a previous statistical analysis over a period of 30 years. The technical term for the responsiveness of crop acres to changes in profitability is the price elasticity of supply. When combined with the data for the Santa Clara County agricultural sector and calibrated against a particular average year, in this case 2010-2011, the resulting economic model can forecast how growers production decisions would change in particular regions, and the effect on farm profitability.

The method used in this study is a standard economic approach used by state and federal agencies including the United States Army Corps of Engineers, United States Bureau of Reclamation, and California Department of Water Resources for project impact evaluations. The model is a flexible framework that could be expanded to measure the effects of the changes in irrigated agriculture on both ecosystem service benefits and open-space benefits. It could also be used to evaluate changes in prices, other input costs, or other policies.

All other factors that may affect future conditions in the agricultural industry are held constant in order to isolate the effect of changes in the agricultural groundwater charge. This is a standard approach for economic analysis. A number of other factors are likely to affect Santa Clara County agriculture in the future but these factors are external to changes in the agricultural groundwater charge. Increased labor and energy costs are likely to be offset by increased agricultural productivity and higher commodity prices. All of these factors are held constant in the analysis.

---

[1] A weighted average across all crops in Santa Clara County shows that the agricultural groundwater charge plus pumping costs is less than 8 percent of average variable costs under all policies considered in this report. This proportion varies by crop and Section 7.3 provides a more detailed discussion and overview.

4. Santa Clara County

This section provides a summary of Santa Clara County land use, agriculture and historical trends driving land use change. The total area of agriculture in Santa Clara County has been on the decline since the 1980's. Increases in productivity and real crop prices have helped keep gross crop revenues constant in real terms and gross revenue per acre has been increasing in recent years.

According to the United States Census Bureau, as of 2011 1.8 million residents call Santa Clara County home. Primary cities at the agriculture-urban interface include Morgan Hill, San Martin, and Gilroy, with populations of 37,882, 7,027, and 48,821, respectively. These cities are immediately surrounded by productive farmland and include average residential home prices above the state average. According to California's Farmland Mapping and Monitoring Program (FMMP), of the 835,000 total acres in the county, 189,000 (23%) are currently developed. Of the remaining acreage, 3% is in productive agriculture, 47% is in range and grazing lands, and the remaining 27% consists of bodies of water and vegetation. Table 1 summarizes land use in Santa Clara County.

Table 1. Farm Mapping and Monitoring Program 2010 Reported Santa Clara County Land Use

Land Use	Acres	Share (%)
Developed	189,130	22.64
Agriculture – Grazing	392,776	47.03
Agriculture – Local	4,327	0.52
Agriculture – Prime	17,271	2.07
Agriculture – State	3,630	0.43
Agriculture – Unique	2,524	0.30
Water Bodies	8,458	1.01
Miscellaneous Other	217,109	25.99
Total	835,225	

4.1 Agricultural Production

The 2011 Santa Clara County Agricultural Crop Report estimates an annual gross value of agricultural production of over $247 million on less than 20,000 harvested acres and an additional 210,000 acres of non-irrigated rangeland. The recently released 2012 Crop Report shows that the gross value increased an additional 5 percent, to just over $260 million. The 2011 gross value of agricultural production includes $86 million from nursery crops and $61 million from mushroom farms. Harvested acreage includes irrigated crops and dry farmed grain hay. Table 2 summarizes County Agricultural Commissioner harvested acreage data by aggregate crop groups starting in 2001. Harvested acres exhibited a slight downward trend over the last 10 years, decreasing from a high of 23 thousand acres in 2003 down to 18.4 thousand acres in 2011.

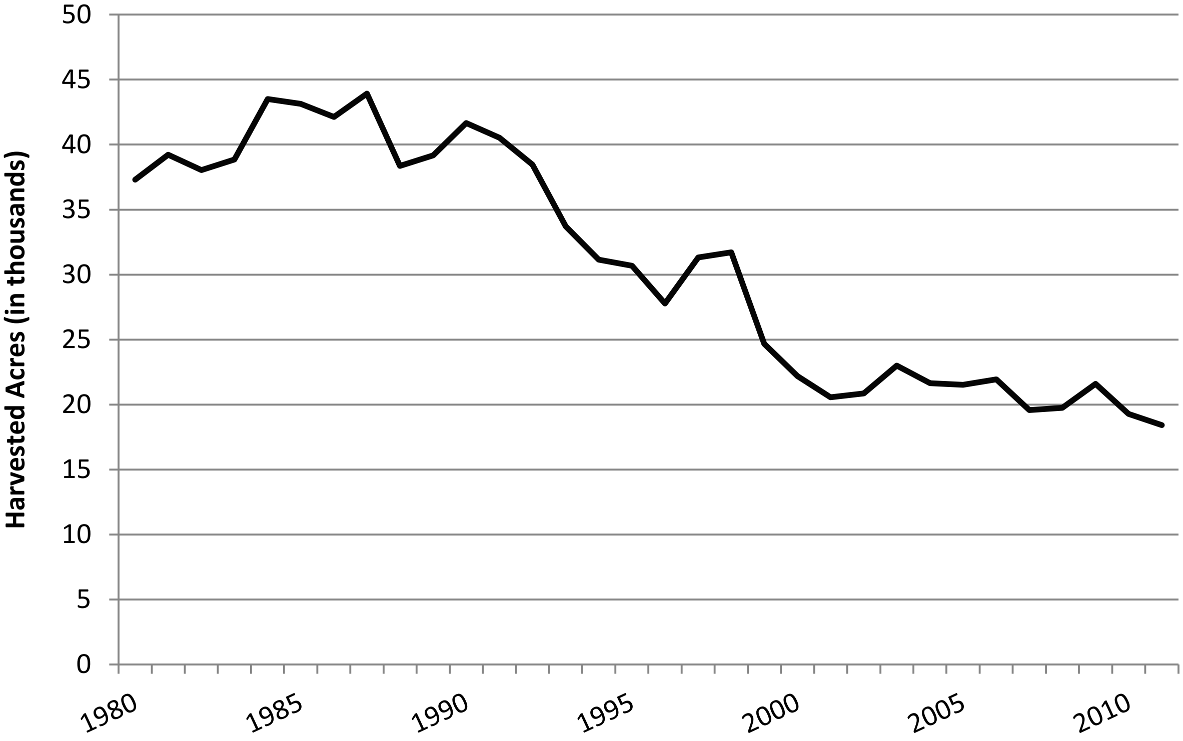
Table 2. Harvested Acres in Santa Clara County, 2001 - 2011

Year	Fruit and Nuts	Field Crops	Onions and Garlic	Vegetables	Processing Tomatoes	Grapes	Dryland Grain Hay	Total
2001	1,847	1,687	590	9,968	525	1,750	4,200	20,567
2002	1,889	2,001	568	10,289	623	1,839	3,642	20,851
2003	1,939	2,176	774	12,726	497	1,854	3,042	23,008
2004	1,674	1,804	691	12,469	169	1,870	2,961	21,638
2005	1,806	2,111	596	12,126	0	1,720	3,163	21,522
2006	1,847	1,903	563	13,160	0	1,750	2,717	21,940
2007	1,862	2,055	623	10,084	0	1,550	3,402	19,576
2008	1,803	2,025	651	9,605	0	1,510	4,143	19,737
2009	1,625	1,476	795	10,482	1,160	1,516	4,530	21,584
2010	1,301	1,082	556	10,008	1,010	1,530	3,790	19,277
2011	1,197	1,339	520	9,248	1,060	1,550	3,510	18,424

Source: Santa Clara County Agricultural Commissioner Annual Crop Reports, 2001 - 2011
Note: Excludes approximately 210,000 acres of non-irrigated rangeland

Figure 1 illustrates the trend for total harvested acres in Santa Clara County. Total acreage has decreased since 1980. Average harvested acres equaled 40,367 per year between 1980 and 1989 and fell to an average of 33,168 and 21,158 in the decades 1990–1999 and 2000–2009, respectively. Given the current difference in the density of cropping across the county, it is clear that the majority of the reduction in acreage took place in North County, where the pressure to convert farmland to commercial, industrial and residential use was the strongest. In addition, traditional crops in North County included soft fruits, which declined in greater proportions than the total harvested acres.

Figure 1. Total Harvested Acres in Santa Clara County, 1980 – 2011



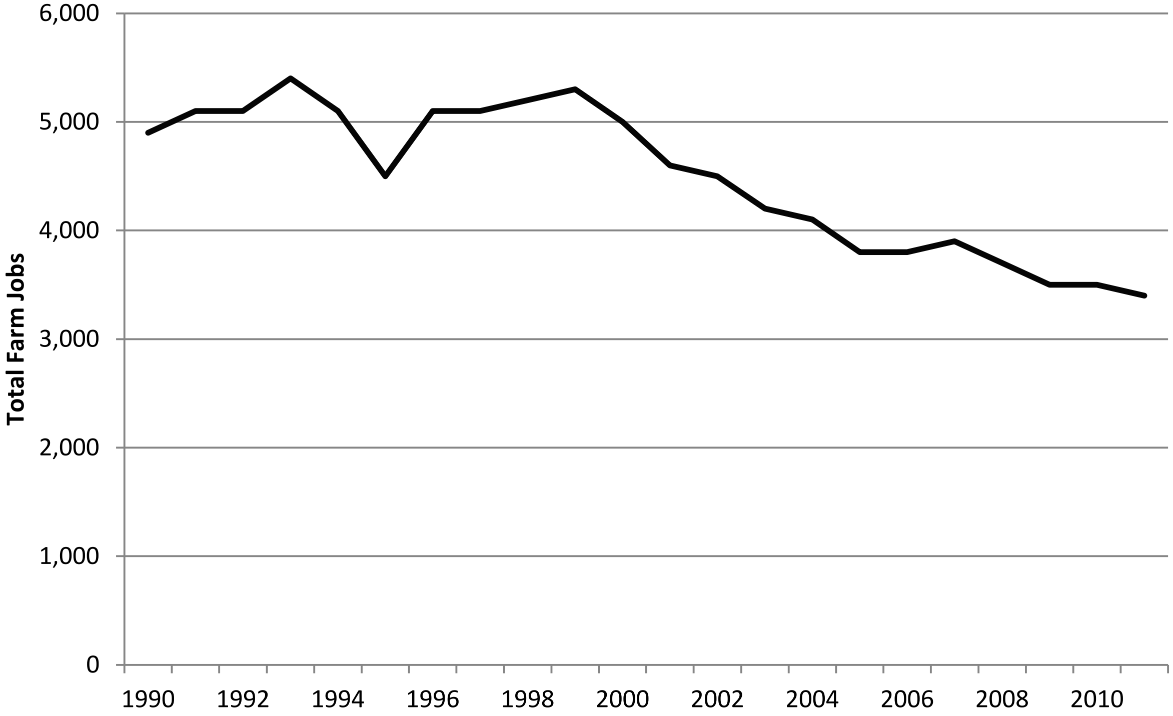
There are a number of trends underlying the changes in total harvested acres. The area planted to grapes has remained fairly stable since 1980, however, like many areas in the Central Valley there has been a conversion in the type of grapes produced from table grapes to wine grapes. This change has coincided with the 1989 designation of Santa Clara Valley as an American Viticultural Area. Garlic acreage has declined by more than 50 percent, a change that is largely attributed to international competition from China. Recent years have seen a steady increase in fresh vegetables, such as bell peppers, in response to strong fresh vegetable demand.

The 2011 gross value of agricultural production ($247 million) includes 26 different commodities with over $1 million in value. Nursery crops accounted for the largest share of gross value ($86 million), which includes miscellaneous bedding plants, roses and shrubs, and turf. Mushrooms are the second most valuable commodity in the county with gross value of $61 million in 2011. Mushroom farms in Santa Clara County include Monterey Mushrooms, South Valley Mushrooms, Royal Oaks Mushrooms, B&D Mushrooms, San Martin Mushrooms, Countryside Mushrooms, and Global Mushrooms. Other top-grossing commodities include bell peppers, fresh tomatoes, lettuce, and miscellaneous greens. For the last decade nursery crops, mushroom farms, and bell peppers have been top grossing commodities in Santa Clara County.

4.2 Agricultural Employment

The California Employment Development Department (EDD) classifies Santa Clara County as part of the San Jose–Sunnyvale–Santa Clara Metropolitan Statistical Area (MSA). EDD shows total farm employment in Santa Clara County in 2011 equaled 3,400 Full Time Equivalent (FTE) jobs in the MSA according to the North American Industry Classification System (NAICS) code(s) 11-000000, total farm jobs. Farm employment has decreased in the MSA since 2008, and the 20 year average is 4,440 FTE farm jobs in Santa Clara County. Farm employment generally mirrors trends in harvested acreage. Figure 2 illustrates total farm jobs in Santa Clara County from 1990 to 2011.

Figure 2. Total Farm Jobs in Santa Clara County, 1990 - 2011



The NAICS data shown in figure 2 do not include indirect and induced jobs supported by the agricultural sector. Indirect jobs include industries that support agriculture such as farm machinery, agricultural chemicals, and fertilizers. Induced jobs are those created by money spent by workers in other industries. For example, a grower employs laborers (direct jobs) and purchases drip tape from a supply store in Gilroy that hires workers (indirect jobs) to support the growers purchases. The farm laborer spends money at local restaurants that hire employees to cook and serve food (induced jobs). Total agricultural employment, including all supporting and supported industries, is higher than that shown in figure 2. Estimation of direct, indirect and induced jobs would require additional analysis with an input-output model of Santa Clara County. Input-output models quantify the relationship between various sectors of the economy and are able to estimate changes in all related industries due to a change in the agricultural sector.

4.3 Agricultural Revenues

The footprint of the agricultural industry in Santa Clara County has been on the decline for a number of years, which can be seen in the declining acreage and employment figures. At the same time the industry has benefited from increased yields through improved efficiency and production practices. International and domestic demand has simultaneously driven strong agricultural prices and land values in recent years.

Figure 3 illustrates gross crop revenue in Santa Clara County since 1980, in constant 2012 dollars. Crop revenue excludes apiary products, livestock, mushroom farms, nurseries, and rangeland. Crop production represents the largest agricultural groundwater user in the county and will be most affected by changes in the agricultural groundwater charge. Figure 3 shows that gross agricultural crop revenue has remained constant in real terms since 1980. This is driven by increases in productivity (yields) and increases in real prices.

Figure 3. Gross Agricultural Crop Revenue in Santa Clara County, 1980 - 2011 (2012 Dollars)

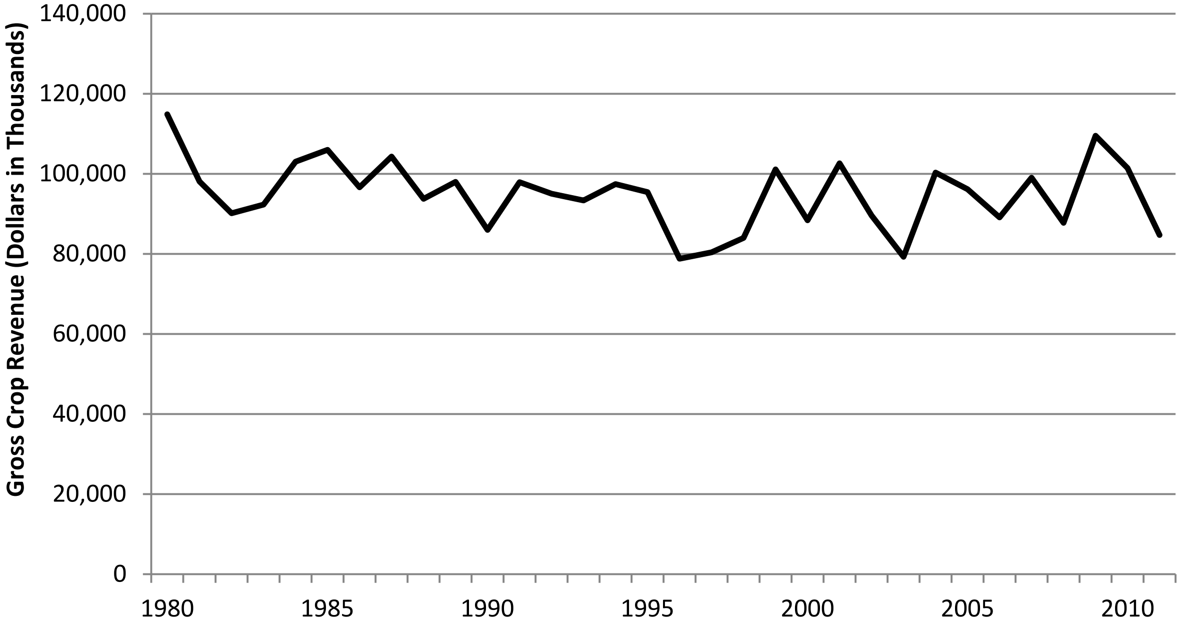
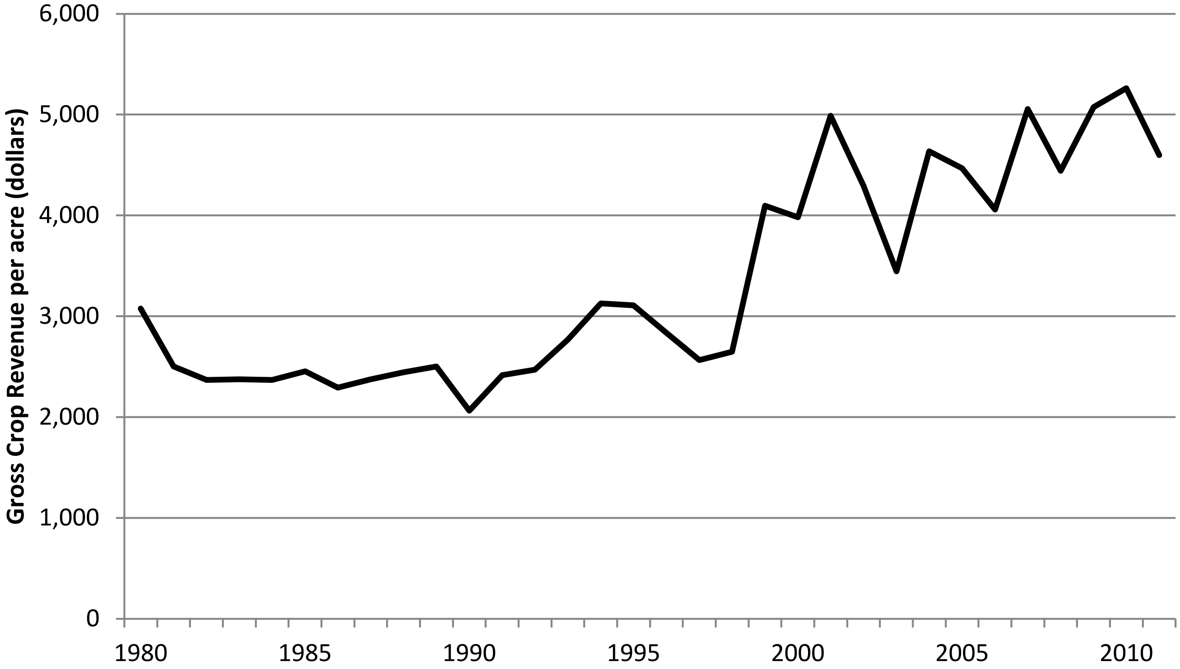


Figure 4 illustrates gross crop revenue per acre from 1980 to 2011, in constant 2012 dollars. Increases in productivity (yields) and real prices and a shift towards higher value more intensive production has led to an increase in gross crop revenues per acre. Although acreage and jobs have declined, the agricultural industry in Santa Clara County currently produces a higher value per unit land than previous years.

Figure 4. Gross Agricultural Crop Revenue per acre in Santa Clara County, 1980 - 2011 (2012 Dollars)



5. The Value of Agricultural Open Space

This section provides an overview of the methods used to estimate the value of different types of agricultural open space in Santa Clara County. The section includes a summary of the estimated value in Santa Clara County and an example application for how to value particular areas of open space. Technical details, references and the logic behind the analysis can be found in technical appendix A.

Open agricultural space provides a range of amenities to communities beyond the direct value of the crops produced and the revenues generated. Many such amenities are positive, such as aesthetic value and scenery for nearby residents, recreation opportunities and prevention of traffic and urban sprawl. Measuring the value of open agricultural land is particularly relevant to Santa Clara County, where fragmented high-tech and residential development is interspersed with high value agriculture. This pattern of development has resulted in a larger agriculture-urban interface (edge) in Santa Clara County than in most urban environments. Figure 5 illustrates land use and the agriculture-urban interface in 2010. The agriculture-urban interface is calculated by applying a 0.25 mile radius to all types of agricultural land reported by the FMMP. Urban development within this radius represents the agriculture-urban interface and is shown in yellow.

Figure 5. Farm Monitoring and Mapping Program (FMMP) Aggregate Land Use, 2010, and Agriculture-Urban Interface

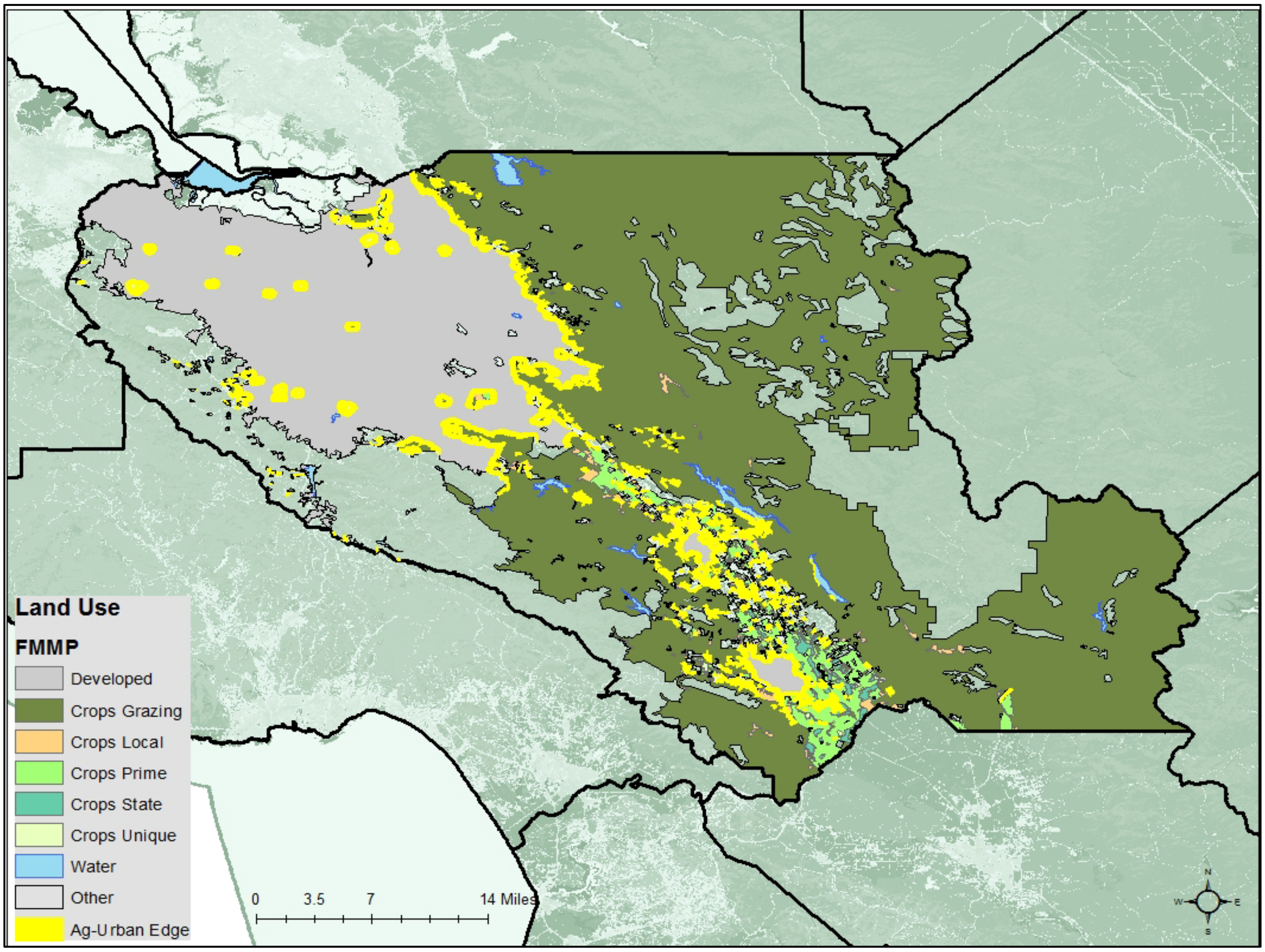


Figure 5 illustrates the concentration of the agriculture-urban edge in South County. This is consistent with the knowledge that as North County has become more developed, agriculture and open space are pushed farther south.

5.1 The Value of Open Space in Santa Clara County

Analysis of Santa Clara County data and review of existing economic studies shows there are three key types of agricultural open space: (i) cropland, (ii) rangeland, and (iii) intensive agriculture. Cropland is land that is actively farmed. Rangeland includes non-irrigated and non-seeded grazing land, native vegetation, and forests. Intensive agriculture includes dairies, mushroom farms, and related production processes that likely generate negative amenities such as noise and odors. These three types of open space were found to provide different economic value and consequently were treated separately in the analysis.

Economists consider open space a non-market good because it has value, but no market where it is traded. Economists have studied the value of open space in different regions using a range of approaches. Over 30 studies were reviewed and 12 studies were identified as relevant for California open space valuation and, in particular, applicable to areas such as Santa Clara County. After careful review and analysis 3 studies were selected to value Santa Clara County open space in cropland, rangeland, and intensive agriculture. Three criteria were used to identify applicable studies:

- The study applied best economic principles, statistical and econometric analysis.
- The study estimated the value of relevant types of agricultural open space.
- The study used data from a region similar to Santa Clara County.

Since agricultural open space is not explicitly traded in a market valuation relies on statistical analysis of nearby home prices. This method relies on econometric (statistical) analysis to decompose the price of a home into the value of its individual attributes. For example, proximity to transportation, quality of the school district, house size, neighborhood characteristics, and a number of other factors can affect the sale price of a home, in addition to proximity to open space. The analysis must control for all other factors that affect the price of a home in order to identify the incremental value attributable to specific types of agricultural open space.

5.1.1. Results

Three types of agricultural open space in Santa Clara County were included in the analysis. To the extent that some homes are located near several land use types, the net effect is a weighted average of the individual estimates provided below. Valuation of all open space in the county would require collecting a comprehensive dataset of all agricultural and urban lands in a geospatial database. Specifically, it would be necessary to know the location of every urban parcel relative to cropland, rangeland, or intensive agriculture.

Analysis of the literature shows that a 0.25 mile proximity to cropland open space increases home values by 2.2% on average. Proximity to forests, rangeland, and native vegetation increases home values further, by 2.56% on average. Some types of open space provides negative value. Proximity within 0.33 mile of intensive agriculture decreases home values by 6.4% on average. Table 3 summarizes the key findings of the analysis.

Table 3. Summary of Open Space Value

Land Use Type	Percent change in nearby home values for 1 parcel converted to open space	Radius (mi)	Study	Location
Cropland	2.20	0.25	Kuminoff (2009)	CA
Forests, rangeland	2.56	0.25	Ready and Abdalla (2005)	MD
Intensive agriculture	-6.40	0.3	Irwin (2002)	PA

5.1.2. Example Application

Consider conversion of 1 parcel from existing urban use to agricultural open space within 0.25 mile of an average home in the cities of Morgan Hill, San Martin and Gilroy. Table 4 summarizes the average change in home value in each location for three open space types. Column 2 lists the average home sale price as of May 2013 in each location. Average home sale prices are compiled from the Zillow Home Value Database and represent an average sale price for all homes sold between January and May 2013. Column 3 shows the change in the average home value if 1 parcel of urban development is converted to crop production. On average, home values increase by 2.2 percent, reflecting the implicit value of open space to the region. For example, in Gilroy this would increase the average value of homes located within 0.25 mile by $9,875. If the parcel was instead converted to rangeland the value would be $11,491. The average home value would decrease if the urban parcel was instead converted to intensive agriculture such as a mushroom farm. These changes in home values hold all other factors constant and consequently represent the implicit value of agricultural open space.

The net value will depend on the quantity and location of different agricultural open space. For example, if a single parcel located within 0.25 mile of an average home in Gilroy was converted from urban development to cropland and another parcel to intensive agriculture, home values near both parcels would decrease in value by 4.2 percent (2.2 - 6.4 percent), on average. The value of open space in this case is -$18,825 ($448,875 x 4.2%).

Table 4. Value of Open Space Example

		Change in home value due to conversion of 1 acre to:		
City	Average Home Price[1]	Cropland	Rangeland	Intensive
Morgan Hill	$581,250	$12,788	$14,880	-$37,200
San Martin	$678,775	$14,933	$17,377	-$43,442
Gilroy	$448,875	$9,875	$11,491	-$28,728
Santa Clara County[2]	$683,025	$15,027	$17,485	-$43,714

[1] Source: January 2013 - May 2013 average, computed from Zillow Home Value Database

[2] County average.

The analysis shows that there are positive effects on home values located in close proximity to agricultural open space. On average, home values increase by 2.2 - 2.56 percent when located close (within 0.25 mile) to cropland or rangeland. There are a few types of agriculture which could have negative effects from odors, noise, and other factors. In Santa Clara County these include mushroom farms and small-scale livestock operations. Proximity (within 0.33 mile) to intensive agriculture such as mushroom farms decreases home values by 6.4 percent on average as a result of negative amenities. Given the checkerboard development pattern in Santa

Clara County and the limited amount of intensive agriculture open agricultural space contributes positive value to Santa Clara County.

6. The Value of Ecosystem Services

This section provides an overview of the methods used to estimate the value of ecosystem services provided by agriculture in Santa Clara County. Technical details, references and the logic behind the analysis can be found in technical appendix B.

Ecosystem services can be broadly defined as the amenities provided by resources and natural systems. Services include maintenance of soil quality, species habitat, clean drinking water, and a general existence value through support provided to a larger ecosystem network. Ecologists have identified over one hundred ecosystem services that can be associated with agriculture and open space. Most services are location-specific such as habitat and water quality. Seven common ecosystem services provided by agriculture are considered and specific attention is paid to flood control and groundwater recharge since these are two components of the District's mission.

6.1 Meta-analysis of the Value of Ecosystem Services in Santa Clara County

Similar to open space, many ecosystem services are non-market goods in that they are not actively traded in a market with an observable price. Ecosystem services are additionally difficult to value because the appropriate geographic scale for analysis varies widely; some services are local in nature, such as pollination, while others are global, such as carbon sequestration. Even after defining the relevant geographic scale, values depend on the location of the field (proximity to important species) and field-specific management practices (organic versus conventional agriculture). In light of these challenges, applied policy research and the academic literature continue to develop new methods to value ecosystem services.

The meta-analysis focused specifically on the groundwater recharge and flood control benefits provided by irrigated agriculture and dry farmed grain hay. Five additional services commonly associated with agricultural production were identified. Ecosystem service values provided by agriculture in Santa Clara County reviewed for this analysis include flood control, groundwater recharge, water quality, pollination, habitat, biodiversity and nitrogen regulation.

Flood control. Agriculture can provide a natural buffer for variation in seasonal water flows and rainfall. Land management practices upstream and downstream affect runoff, drainage and the frequency of flood events. In some areas agriculture can be managed for both crop production and as a seasonal floodplain. Agriculture typically has a lower cost for a given level of flood risk than residential and commercial development.

Groundwater recharge. Deep percolation from irrigation and precipitation will result from some portion of applied water in excess of consumptive use. This proportion depends on field soil characteristics, slope, crop type and irrigation practices.

Water quality. Surface runoff and deep percolation of water from irrigation and precipitation on agricultural land can increase or decrease water quality. Excessive nitrogen application can lead to significantly decreased water quality. Less intensive agriculture such as rangeland can provide a natural filter for water.

Pollination. Wild pollinator populations have recently been on steady decline in California. Agriculture provides natural habitat for pollinators.

Habitat. Conversion from native vegetation to agriculture can destroy habitat for some species. However species such as the Swainson's Hawk and other predatory birds benefit from hunting conditions on open fields.

Biodiversity. A diverse crop mix and rotation system functions as a natural break for pest and disease cycles. It also provides flexibility for producers to respond to changes in agricultural prices and import and export market conditions.

Nitrogen regulation. Excessive nutrient runoff is a primary cause of eutrophication of surface water. Agriculture is a primary contributor to this problem in many regions, although rotation systems and other field management decisions can be used to manage nitrogen application and reduce runoff.

Agriculture provides ecosystem services and many disservices. The cost of ecosystem disservices from agriculture should not be understated. For example in the Llagas subbasin, the rate of domestic well contamination above the nitrate MCL is known to be high, and the primary causes include fertilizers used in agriculture and septic tanks. This analysis focuses on the value of ecosystem services but careful attention should be paid to tradeoffs between the benefits described in this report and potential costs along other dimensions.

Several dozen studies were reviewed and 22 were identified as relevant for Santa Clara County. From these, 4 studies were identified for use in the meta-analysis. The decision to include the study in the meta-analysis was based on three criteria:

- The study estimates some or all of the 7 ecosystem service values for agriculture.
- The study used data from a region with a large agriculture-urban interface similar to that found in Santa Clara County.
- The study was peer-reviewed or part of a public report that was based on peer-reviewed publications.

Additional estimates of the value of groundwater recharge from agriculture were calculated to update values identified in the meta-analysis. The additional analysis used District and California Department of Water Resources water use data to estimate deep percolation using a soil-water balance for major crops in the county.

6.1.1. Results

Table 5 summarizes total ecosystem service values for the seven services considered in this analysis.

Flood control ecosystem service values range between $42 and $86 per acre per year. The value of flood control ecosystem services is typically estimated using an avoided cost approach. In the avoided cost framework the estimated value of an agricultural acre of flood control benefits is based on the change in risk and additional cost of flood events if the land were converted to urban use. Values in Santa Clara County are likely to be higher given the high-value urban land in North County, and significant agriculture-urban interface in South County.

Groundwater recharge ecosystem service values identified in the literature review range between $22 and $44 per acre per year. Groundwater recharge benefits are estimated using a soil-water balance approach and include the benefits from deep percolation of irrigation water and precipitation. Irrigation and precipitation in excess of consumptive use goes to soil capacity, surface runoff, or deep percolation. Studies reviewed for the meta-analysis typically make location specific adjustments for the proportion of soil capacity and surface runoff in order to estimate the amount of groundwater recharge provided by an average acre. The studies identified in the literature review are not representative of Santa Clara County water values and conditions. This estimate is updated in the following section.

Table 5. Meta-Analysis of the Total Value of Ecosystem Services Provided by Agriculture

Service	Total Value ($/ac per year)	Summary Notes
Flood Control	$42 – $86	*Santa Clara County is likely at or above the high end of this range due to high cost of flood events.*
Groundwater Recharge	$22 – $44	*This value represents the average for direct recharge from irrigation and precipitation. Santa Clara County has a higher value and this estimate is further refined.*
Water Quality	$27	*Value represents an average, range varies from positive to negative depending on the crop.*
Pollination	$19 – $64	*None.*
Habitat	Varies	*Estimates are both crop and species-specific. Excluded from this analysis.*
Biodiversity	$31	*None.*
Nitrogen Regulation	$0 – $433	*Estimates are crop-specific and can be negative in some cases.*

Additional analysis was performed to refine estimates of the groundwater recharge value in Santa Clara County. The analysis estimates groundwater recharge from irrigated agriculture and dry farmed grain hay and does not include other sources of recharge such as that in developed areas. The amount of groundwater recharge depends on factors such as soil capacity and surface runoff. These factors are varied in the analysis in order to generate a lower and upper-bound scenario. Table 6 summarizes the results of the analysis. Groundwater recharge is estimated at between 10,686 and 13,140 acre-feet per year. This translates into an annual average of 0.55 to 0.68 acre-feet of groundwater recharge provided by an acre of harvested agricultural land in Santa Clara County. The average cost of an acre foot of agricultural water to the District is $246 per acre-foot (as of Fiscal Year 2014) and this is used to value the groundwater recharge. A cost of $246 per acre foot of agricultural water and recharge of between 0.55 and 0.68 acre-feet per acre implies a groundwater recharge ecosystem service value between $135.30 and $167.28 per acre per year. Assumptions used for the calculation can be found in technical appendix B.

The groundwater recharge ecosystem service value represents the direct total value for an agricultural acre. If an acre is converted to urban development it would be necessary to estimate the difference in recharge between the two land use types in order to calculate the net effect.

Table 6. Groundwater Recharge Ecosystem Service Value in Santa Clara County

Scenario	Groundwater recharge (af/year)	Acre-feet per acre per year	Value per af ($/af)	Groundwater Recharge Value ($/ac per year)
Low Assumptions Estimate	10,686	0.55	$246	$135.30
High Assumptions Estimate	13,140	0.68	$246	$167.28

Taking the meta-analysis results for the value of flood control benefits presented in table 5 and the groundwater recharge estimates presented in table 6, the estimated total value of groundwater recharge and flood control ecosystem services provided by agriculture to Santa Clara County is between $177.30 and $253.28 per acre per year.

Ecosystem services are difficult to define and challenging to value. Work continues to develop the scientific methodologies to understand ecosystem processes and the economic approaches to value individual components.

7. Analysis of the Agricultural Groundwater Charge

This section provides an overview of the methods used to estimate the direct costs to Santa Clara County growers resulting from changes in the agricultural groundwater charge. Technical model details, references and the logic behind the analysis can be found in technical appendix C.

The ability to analyze changes in the groundwater charge under short run and long run conditions requires an economic model of the agricultural economy in Santa Clara County which is able to reflect the incremental effects of changes in water costs. Changes in local economic activity occur gradually as costs and benefits change, so there is a corresponding difference between short run and long run analysis. Grower response to increasing groundwater charges will be a smooth adjustment, rather than a sudden shift out of production.

7.1. Groundwater Charge Scenarios

The analysis considers three scenarios over a 10 year time horizon:

- Baseline
- Agricultural groundwater charge increasing to 10 percent of M&I over a 10-year time period
- Agricultural groundwater charge increasing to 25 percent of M&I over a 10-year time period

Table 7 summarizes the agricultural groundwater charge in the three scenarios. As shown, baseline conditions have the agricultural groundwater charge increasing from the current level (FY 2014) of $18.30 per acre-foot to $18.90 per acre-foot in FY 2015, up to $24.82 in FY 2024. The agricultural groundwater charge increases to $41.39 and $103.36 by 2024 in the 10 percent and 25 percent of M&I scenarios, respectively.

Table 7. Agricultural Groundwater Charge ($/af) by Fiscal Year

Scenario	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Baseline	18.90	19.50	20.10	20.70	21.30	21.91	22.51	23.11	23.71	24.82
10% of M&I	19.86	21.55	23.38	25.37	27.52	29.86	32.40	35.16	38.14	41.39
25% of M&I	21.76	25.88	30.77	36.58	43.50	51.72	61.49	73.12	86.93	103.36

The direct economic cost to growers from changes in the agricultural groundwater charge equals the difference between the baseline scenario and the 10 and 25 percent scenarios, respectively.

7.2. Santa Clara County Agricultural Production Model

An economic model of agricultural production in Santa Clara County was constructed for this analysis. The model includes 18 crop groups and their corresponding revenues and production costs. The model is defined over 3 groundwater areas including the Santa Clara Plain, Coyote Valley, and Llagas Subbasin. Economic and land use data were collected for the Santa Clara County agricultural sector and the model was calibrated against a particular average year, in this case 2010-2011. The resulting economic model is used to forecast how growers production decisions would change in particular regions in response to higher agricultural groundwater costs, and the effect on farm profitability.

Table 8 summarizes crop acreage across the three Santa Clara County model regions based on 2010-2011 averages.

Table 8. Santa Clara County Model Crop Acreage, 2010-2011 Average

Crop Group	Santa Clara Plain	Coyote Valley	Llagas
Alfalfa	286	91	0
Apricot	105	41	76
Beans	6	390	437
Cherries	0	199	336
Citrus	118	13	100
Cucurbits	0	564	404
Fresh Tomatoes	0	26	732
Garlic	0	54	245
Grain	1,155	579	1,916
Lettuce	15	530	1,908
Onions	0	12	227
Other Truck	44	628	3,610
Pasture	85	22	361
Processing Tomatoes	0	21	1,014
Strawberries	0	19	76
Sweet Corn	21	392	753
Vines	657	324	559
Walnuts	29	24	111

7.3. Groundwater Costs as a Percent of Variable Costs

Small changes in the agricultural groundwater charge require an estimation framework that can capture the incremental responses of growers. A standard crop budget accounting approach cannot capture incremental grower adjustments because it lacks economic information, such as observed responsiveness to changes in prices and costs, found in classical economic models. Beyond this, an accounting approach does not acknowledge cross-crop effects and the fact that many crops are grown in a rotation that will likely adjust as relative crop profitability changes.

Table 9 summarizes the agricultural groundwater charge as a percentage of variable costs under the baseline, 10 percent of M&I and 25 percent of M&I scenarios. Without proprietary information it is not possible to compute the groundwater costs as a percentage of grower profits. Estimates represent a weighted average over all crop acres in the county. The proportion of variable production costs attributable to the agricultural groundwater charge equals less than 1 percent, on average, under baseline conditions. This increases to a maximum just under 5 percent of variable costs in the 25 percent scenario in fiscal year 2024.

Underlying the weighted averages are large variations by crop type. For flood irrigated water-intensive crops such as alfalfa, the groundwater charge accounts for 14 to 45 percent of variable production costs in the baseline (year 2015) and 25 percent of M&I (year 2024) scenarios, respectively. Other crops such as lettuce have variable production costs that are driven by yield and the corresponding harvest costs such that the groundwater charge accounts for less than 0.3 to 2 percent of variable production costs.

Table 9. Agricultural Groundwater Charge as a Percent of Variable Production Costs, Weighted Average by Fiscal Year

Scenario	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Baseline	0.89	0.92	0.95	0.98	1.00	1.03	1.06	1.09	1.12	1.17
10% of M&I	0.94	1.02	1.10	1.19	1.29	1.40	1.52	1.65	1.78	1.93
25% of M&I	1.02	1.22	1.44	1.71	2.03	2.40	2.84	3.36	3.97	4.69

Table 10 summarizes the total groundwater cost as a percent of variable production costs under baseline, 10 percent of M&I, and 25 percent of M&I scenarios. The total groundwater cost includes the amortized fixed cost of the pump and well plus the variable operating cost of the pump and minor upkeep and maintenance expenses in addition to the agricultural groundwater charge. The corresponding proportion of variable costs is higher, ranging from just over 4 percent to just under 8 percent of variable production costs.

Table 10. Total Groundwater Cost as a Percent of Variable Production Costs, Weighted Average by Fiscal Year

Scenario	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Baseline	4.12	4.15	4.17	4.20	4.23	4.25	4.28	4.30	4.33	4.38
10% of M&I	4.16	4.24	4.32	4.40	4.50	4.60	4.71	4.83	4.95	5.09
25% of M&I	4.25	4.43	4.64	4.89	5.18	5.54	5.95	6.44	7.01	7.68

Groundwater costs, both the agricultural groundwater charge and total groundwater cost, represent a relatively small portion of variable production costs. Even though groundwater is a relatively small portion of variable costs, growers respond economically to incremental changes in the groundwater charge. There is a corresponding cost to growers and the county. The following sections highlight this finding and the results of the analysis.

7.4. Direct Costs to Growers

The model framework estimates the direct cost of the change in the agricultural groundwater charge to growers at each point in time as the difference between baseline conditions and each of the two groundwater charge scenarios. There are four key direct costs to growers:

- Shifts in the regional crop mix (net revenue loss)
- The decision to permanently fallow land (fallow land cost)
- Increased groundwater cost to all growers (additional groundwater cost)
- Cost to mushroom farms and nurseries

Growers are likely to shift the regional crop mix and alter rotations in response to changes in the cost of groundwater. Changes in production costs alter the relative profitability between crops and profit maximizing growers are expected to adjust land use patterns accordingly. This effect is additionally governed by the acreage response elasticities which show how growers have historically responded to changes in production costs and crop prices. The cost of the shift in crop mix depends on the crops brought into and out of production which is estimated using the Santa Clara County model.

As water costs increase it may become economically optimal to fallow less productive land. The cost of land out of production is equal to the land rental rate, which in Santa Clara County averages $300 per acre.

All growers in Santa Clara County would face higher groundwater charges per acre foot. The difference between the baseline conditions and the 10 percent or 25 percent scenario, multiplied by the total acre-feet of groundwater used represents the additional cost to growers. Total agricultural groundwater use varies with the estimated crop mix but is generally around 27,800 acre-feet per year. The method used to calculate the total groundwater cost can be found in technical appendix C.

Costs to mushroom farms and nurseries are treated separate from standard crop production. Changes in these industries are more likely to be driven by changes in regional demand for bedding plants and increased competition in mushroom production from Pennsylvania, Canada, and China. Consequently, mushroom farm and nursery response to changes in the groundwater charge is modeled as perfectly inelastic. This means that these industries bear the full cost of the increase in the groundwater charge and do not shift production or pass on costs to consumers.

The incremental cost to growers represents the difference between baseline conditions and the respective policy at each point in time. The total cost is the sum of the incremental costs. Due to general price inflation a dollar today is worth more than a dollar in the future. The sum of the incremental costs is consequently "discounted" back to a present value figure. This represents the present value of the total cost to growers.

7.4.1. Agricultural Groundwater Charges at 10 Percent of M&I Rates

Table 11 summarizes the cost to growers, relative to baseline, when the groundwater charge increases to 10 percent of M&I rates by 2024. The table shows the incremental cost for each of the four components for each of the 10 years of phase-in.

The total cost to growers is equal to the present discounted value of the 10 year stream of losses, plus the infinite future stream of losses from year fiscal year 2024 forward. Growers face an increasing incremental cost for the first 10 years of phase in, then it is assumed that the difference between baseline and 10 percent of M&I rates remains constant into the future. To the extent that relative rates converge or further diverge the present value of the total cost to growers will decrease or increase, respectively. Using a standard discount rate of 5 percent, the present value of the total cost to growers is $6.96 million.

Table 11. Direct Cost to Growers, by Fiscal Year (dollars in thousands) for 10 percent of M&I

Cost to Growers	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Additional Groundwater Cost	25.3	54.0	86.5	123.1	163.9	209.5	260.5	317.4	380.0	436.3
Net Revenue Loss	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.7
Land Fallow Cost	0.2	0.5	0.8	1.2	1.7	2.3	3.0	3.8	4.7	5.2
Mushroom and Nursery	1.3	2.7	4.3	6.2	8.2	10.5	13.1	15.9	19.1	21.9
Total Cost	26.8	57.4	91.8	130.9	174.4	223.0	277.6	338.3	405.2	465.0

Results show that the largest cost to growers is the cost of additional groundwater. Changes in the crop mix (reflected in net revenue loss) and increased land fallowing are relatively minor factors in response to relatively small increases in the groundwater charge.

The general trend underlying the analysis is an incremental shift out of lower-value and higher water use crops, that are not grown as part of a higher value rotation, into higher-value and lower water use crops. Incremental costs increase from $26,800 in fiscal year 2015 to $465,000 in fiscal year 2024. Costs to growers increase at an increasing rate as the groundwater charge increases. From fiscal year 2024 onward the incremental costs are assumed constant at $465,000.

7.4.2. Agricultural Groundwater Charges at 25 Percent of M&I Rates

Table 12 summarizes the cost to growers, relative to baseline, when the groundwater charge increases to 25 percent of M&I rates by 2024. The table shows the incremental cost for each of the four components for each of the 10 years.

The total cost to growers is equal to the present discounted value of the 10 year stream of losses, plus the infinite future stream of losses from fiscal year 2025 into the future. Using a standard discount rate of 5 percent, the present value of the total cost to growers is $35.91 million.

Table 12. Direct Cost to Growers, by Fiscal Year (dollars in thousands) for 25 percent of M&I

Cost to Growers	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Additional Groundwater Cost	75.4	168.1	281.1	418.1	584.2	783.9	1,022.8	1,299.7	1,620.4	1,975.9
Net Revenue Loss	0.4	0.9	1.5	2.3	3.1	4.1	15.6	75.2	159.9	268.3
Land Fallow Cost	1.2	2.7	4.7	7.0	9.9	13.4	22.0	53.6	99.0	164.7
Mushroom and Nursery	3.8	8.4	14.1	21.0	29.3	39.4	51.5	66.0	83.5	103.7
Total Cost	80.8	180.2	301.4	448.4	626.6	840.8	1,111.8	1,494.5	1,962.8	2,512.6

Results show that, as with the 10 percent scenario, the largest cost to growers is the cost of additional groundwater. Shifting crop mix and increased land fallowing are relatively minor occurrences over small changes in the groundwater charge. Net revenue losses (shift in crop mix) begin to increase at an increasing rate beginning in 2021 as the agricultural groundwater charge exceeds $61 per acre foot.

Incremental costs increase from $80,800 in fiscal year 2015 to over $2.51 million in fiscal year 2024. Costs to growers increase at an increasing rate as the groundwater charge increases. From fiscal year 2024 forward the incremental costs are assumed constant at $2.51 million.

7.5. Changes in Irrigated Acres

Growers are expected to fallow some land in response to higher groundwater costs. Fallow land corresponds to land permanently taken out of production in response to higher groundwater charges, not land fallow as part of a crop rotation. Land out of production is expected to come from lower quality production conditions and farms that already operate with higher production costs. Growers who fallow land will lose the ability to rent the land, reflecting the fixed costs of production. Land rents for an average of $300 per acre in Santa Clara County. Table 13 summarizes total land out of production in response to higher agricultural groundwater charges.

Table 13. Fallow Acres due to Increased Groundwater Charge

Fallow Land (acres)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
10 percent Scenario	1	2	3	4	6	8	10	13	16	17
25 percent Scenario	4	9	16	23	33	45	73	179	330	549

The analysis shows that total land out of production is expected to be a small proportion of the total harvested land area. The maximum land out of production in the 10 percent scenario (17 acres) is less than 1 percent of total harvested acres.

When the groundwater charge increases to 25 percent of M&I rates by 2024, total land out of production is still a relatively small proportion of total acreage. A maximum of 549 acres out of production corresponds to less than 3 percent of total county harvested acreage.

The agricultural community will correctly note that there are a range of external pressures that are not captured by this analysis. Increases in all other production costs are held constant in real terms in order to isolate the effect of increasing the agricultural groundwater charge. Conversely agricultural producers have enjoyed a steady increase in real prices and farm productivity in recent years. Increases in agricultural prices and productivity are held constant in order to isolate the effect of increasing the agricultural groundwater charge. All other external costs and benefits are held constant in the analysis.

The analysis considers changes within the Santa Clara County agricultural economy and the decision of whether or not to fallow land is fundamentally a decision about whether to continue farming in Santa Clara County. Some growers may decide to shift production to other regions such as Salinas or the Central Valley, or areas to the south in San Benito County. While this decision is partially captured by the acreage response elasticities implicit in the model, it is likely that response in some parts of the county may be more elastic. Consequently, fallow acreage estimates in this analysis should be viewed as conservative estimates.

7.6. Costs to the County Economy

This analysis summarizes the cost to growers from increases in the groundwater charge. This study has not considered the effects on the Santa Clara County economy, such as jobs, output value, and county tax revenues. Additionally, this study is concerned with the direct cost and has not estimated indirect and induced costs on the broader economy. Estimation of total costs to the county and agricultural employment would require additional analysis with a regional input-output model of Santa Clara County, such as IMPLAN.

8. Summary of Findings

This study has provided an independent and quantitative assessment of the value of agricultural open space, the value ecosystem service provided by agriculture, and the direct economic costs to growers from changes in the agricultural groundwater charge in Santa Clara County.

The value of agricultural open space was found to be generally positive. Cropland increases nearby (within 0.25 mile) home values by 2.2 percent and open rangeland increases values by 2.56 percent. The total value of an agricultural acre depends on the location and number of surrounding homes. Intensive agriculture decreases home values within 0.33 mile by 6.4 percent. The net effect of loss (or addition) of agricultural open space depends on the location, homes, and types of open space land use.

The value of ecosystem services provided by agriculture is a relatively new area of research and methods are still being refined. A meta-analysis and additional county-specific estimates found that the total ecosystem service value of flood control and groundwater recharge is between $177.30 and $253.28 per acre per year. Future studies should be location specific and be aware of the costs of agricultural runoff and other disservices.

Baseline conditions and two agricultural groundwater charge scenarios were evaluated using an economic model of Santa Clara County agriculture. Results of the analysis show that small changes in the agricultural groundwater charge will lead to incremental production adjustments by growers, but that the agricultural industry will not collapse. Total land fallowing is minimal. When the agricultural groundwater charge increases to 10 percent of M&I rates over a 10 year period, the present value of the total cost to growers is $6.96 million. Total land fallowing is 17 acres, less than 1 percent of total harvested acres. When the agricultural groundwater charge increases to 25 percent of M&I rates over a period of 10 years, the present value of the total cost to growers is $35.91 million. Total land fallowing is 549 acres, less than 3 percent of total harvested acres.

Technical Appendix A: Value of Open Space

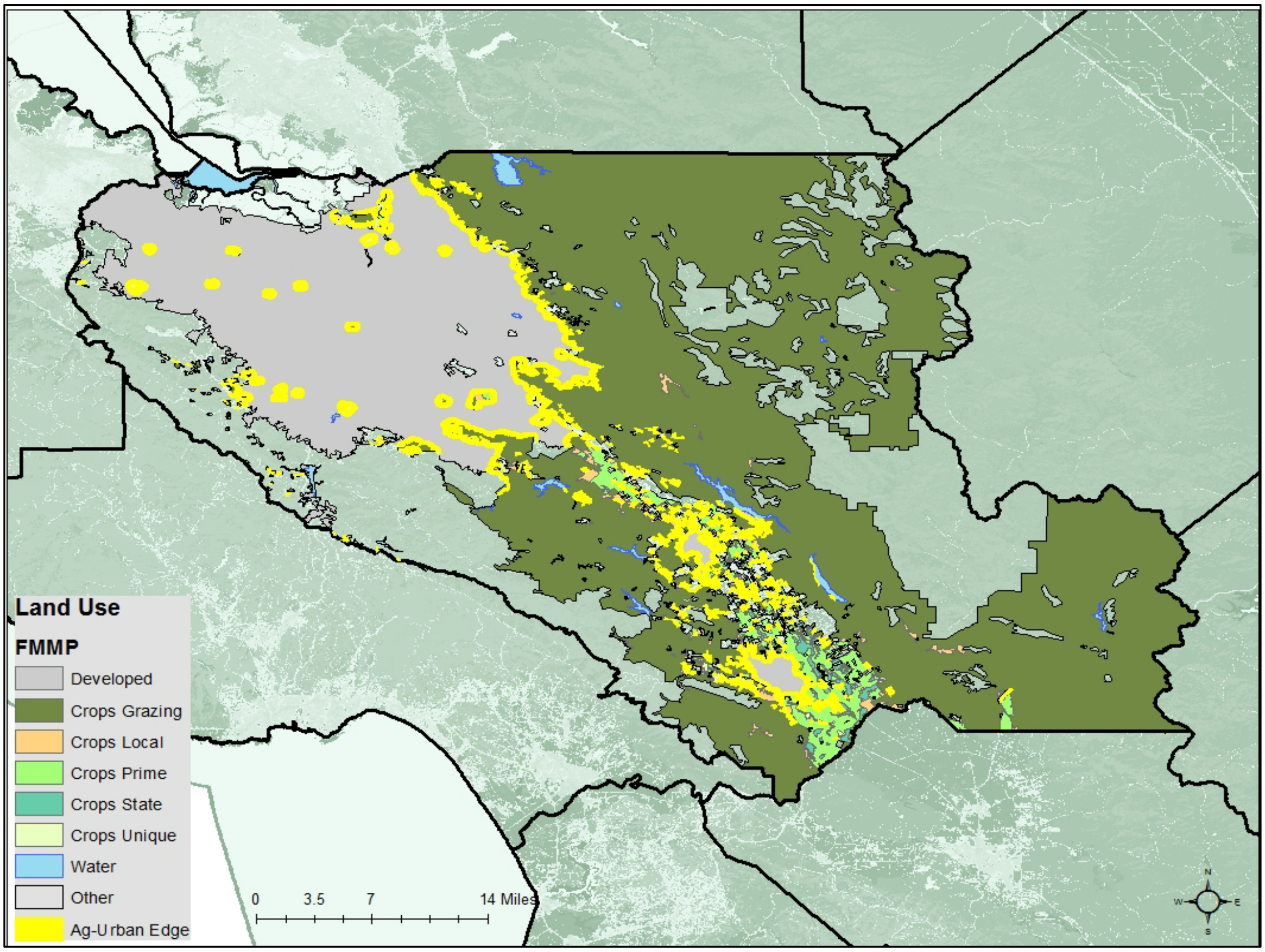
This technical appendix provides an independent and quantitative assessment of the value of agricultural open space in Santa Clara County using a comprehensive literature review and meta-analysis.

A.1. The Value of Open Space in Santa Clara County

Open agricultural space provides a range of amenities to a community beyond the direct value of the crops produced and the revenue generated. Many such amenities are positive, such as aesthetic value and scenery for nearby residents, recreation opportunities, ecosystem services (flood control, water supply, water quality, habitat, recreation, and extraction), and prevention of traffic and urban sprawl. Because of these benefits, state and local governments have instituted various policies designed to preserve agricultural land, including zoning changes and purchases of conservation easements. The District encourages preservation of open space through the Open Space Credit, which essentially functions as an agricultural irrigation water subsidy designed to encourage agricultural lands in the county. Quantifying the value of open agricultural land is particularly relevant to Santa Clara County, where fragmented high-tech and residential development is interspersed with high value agriculture.

Figure A1 illustrates land use and the agriculture-urban interface in 2010. Agricultural open space includes cropland, rangeland, and intensive agriculture. Open space may provide both positive and negative amenities depending on the type and location. Correctly valuing open space requires careful statistical analysis and should be tailored to the specific region of interest. The analysis in this appendix includes a comprehensive review of the economic literature on open space valuation in order to identify the studies most applicable to Santa Clara County.

Figure A1. Farm Monitoring and Mapping Program (FMMP) Aggregate Land Use, 2010, and Agriculture-Urban Interface



Open space is what economists refer to as a non-market good because it has value, but not a market where it is traded. There are a number of methods that economists use to value such goods, which are discussed in subsequent sections of this technical appendix. Non-market values are typically classified as either use or non-use values. Use values are benefits related to seeing or using the open space (e.g. pleasant views, experiencing improved water quality, having increased opportunity for viewing wildlife), while non-use values are instead derived from simply knowing that the open space exists. This analysis relies on a comprehensive review of the economics literature and public policy reports valuing open space in other regions using a range of methods. Relevant studies are identified and used to generate relevant values for Santa Clara County. This analysis should be thought of as a representative acre analysis in that it estimates the value of an average representative acre of agricultural open space situated next to an average representative urban development as reflected in the average value of nearby homes.

A.1.1 An Overview of the Value of Open Space

Contingent Valuation (CV) methods, typically in the form of stated or revealed preference, are commonly used to value non-market goods. CV methods recognize that there is no market in which to establish the price of open space and instead use other sources of information to statically infer the price. Valuation methods include:

- Stated Preference
- Revealed Preference

- Cost of Travel
- General Equilibrium
- Cost of Service

Stated preference methods rely on carefully designed surveys that ask property owners to state what they are willing to pay to avoid conversion of existing open space to alternative uses. Revealed preference analysis measures how property values change when they are associated with changes in open space, holding all other factors constant. The revealed preference method relies on econometric (statistical) analysis to decompose the price of a home into individual attributes. For example, proximity to transportation, school district, house size, neighborhood, and a number of other factors can affect the sale price of a home, in addition to proximity to open space. In order to correctly value open space, the analysis must control for all other factors that affect the price of a home. Other less common valuation methods include cost of travel, general equilibrium modeling, and cost of services approaches.

Agricultural open space provides direct and indirect benefits. Direct benefits include those benefits accrued to agricultural land owners and owners of adjacent properties. For example, the presence of agricultural open space may provide growers with a more robust agricultural industry, such as cheaper and more readily available input and labor markets. Residential owners of adjacent properties may see increased property values from proximity to agricultural open space and this translates into greater property tax income for the county. Indirect benefits include preservation of land base for agriculture to expand and respond to changing market conditions, preservation of rural character, and prevention of urban sprawl.

The value of open space depends on the type of land use. Mushroom farms will not provide the same aesthetic or biodiversity value as alfalfa stands. Economic studies have additionally shown different values for permanent and temporary open space. Homeowners place a higher value on nearby land that is zoned (or otherwise restricted) for permanent open space.

A.1.2. Positive and Negative Amenities

Open space may have both positive and negative amenity value. Some common negative amenities due to agricultural production:

- Noise
- Odors
- Dust, pesticides
- Increased agricultural traffic

Negative amenities include increased noise from agricultural production processes, which may decrease the value of surrounding homes. For example, a study by Ready and Abdalla (2005) of housing prices in the Philadelphia area shows that open space (including agricultural space) has a positive impact on house prices within 400 meters, but that larger-scale livestock operations (Confined Animal Feeding Operations, or CAFOs) can reduce house prices out to 1,600 meters by as much as 6.4 percent.

Some common positive externalities:

- Aesthetic value
- Recreation
- Water Supply
- Ecosystem benefits

- Prevention of noise, congestion, and other effects of sprawl
- Agricultural marketing and development

Positive amenities are those that are expected to increase nearby home values. For example, agricultural open space reduces urban sprawl, traffic, and noise, which homeowners likely desire.

Although there are certain situations where agricultural land may provide negative amenities to the surrounding area, most studies find that agricultural land generates positive nonmarket benefits. Analysis of Santa Clara County data and review of existing economic studies shows there are three key types of agricultural open space: (i) cropland, (ii) rangeland, and (iii) intensive agriculture. Cropland is land that is actively farmed. Rangeland includes non-irrigated and non-seeded grazing land, native vegetation, and forests. Intensive agriculture includes dairies, mushroom farms, and related production that likely generate negative amenities such as noise and odors.

A.2. Meta-Analysis of the Value of Open Space

An exhaustive literature review focused on identifying studies relevant to valuing open space in Santa Clara County. Santa Clara County is unique for several reasons. First, the county hosts a significant concentration of high-tech firms. Economies created by large tech firms attract additional startups and employees to the area and increase pressure on both residential and commercial development. Indicators for the macro-economy have been steadily increasing since the worst of the recession in the Fall of 2008, and pressure on commercial and residential development has followed. In addition to a large tech industry Santa Clara County provides productive farmland for a range of high value agriculture including fruit and nut orchards and bell peppers. Residential and commercial development in North County has pushed remaining agriculture into South County, which has resulted in a checkerboard pattern of productive farmland and high-value commercial and residential development.

Economists have studied the value of open space using a range of approaches. Over 30 studies were reviewed and 12 studies were identified as potentially relevant for California areas. After careful review and analysis 3 studies were selected to value Santa Clara County open space in cropland, rangeland, and intensive agriculture. Three key criteria were used to identify applicable studies:

- The study estimates some or all of the 7 ecosystem service values for agriculture.
- The study used data from a region with a large agriculture-urban interface similar to that found in Santa Clara County.
- The study was peer-reviewed or part of a public report that was based on peer-reviewed publications.

The study by Kuminoff (2009) was identified as most applicable for the value of cropland agricultural open space. Kuminoff estimates a revealed preference model using data from San Joaquin County. His analysis allows for both positive and negative amenity values for different types of open agricultural space. He estimates that converting one acre of cropland to urban development within 0.25 mile of the average home would reduce the price by 2.2 percent (95 percent Confidence Interval = [2.1, 2.8]) on average. For a small share (3–7 percent) of homes that are directly next to cropland, the negative amenities provided by agriculture dominate such that converting an acre of cropland to urban development would result in higher home values. Kuminoff concludes that there is evidence that open agricultural land provides generally positive value to nearby urban development.

Cropland and the agriculture-urban interface are different between San Joaquin and Santa Clara Counties for a number of reasons. Santa Clara generally produces higher value agriculture and has higher per-capita income, land and real estate values. It is not possible to determine whether these differences would bias estimates up or down when extrapolating to Santa Clara County without additional data. San Joaquin and Santa Clara Counties are areas with a similar agriculture-urban interface and, although they are subject to different county-level policies, they are subject to the same state policies and trends. San Joaquin County represents the best available proxy for Santa Clara County for which an existing study was available. The study by Kuminoff (2009) captures the essential aspects of the value of agricultural open space and results show that proximity to cropland increases home values for a large majority of single-family homes near the urban-agricultural border.

The study by Irwin (2002) was identified as most applicable for the value of forest and rangeland open space. Irwin estimates a revealed preference model to value open space using data from Maryland counties. Irwin's analysis estimates the value of open space in crop production, in addition to open space in forests and rangelands. Irwin estimates that converting one acre of rangeland to urban development within 0.25 mile of the average home would reduce the price by 2.6 percent (95 percent Confidence Interval = [2.2, 3.1]) on average.

Maryland represents a significantly different geographic region than Santa Clara County. Maryland has different development laws, home values, resident preferences and transportation options. All of these factors significantly affect confidence in applying Maryland results to Santa Clara County. However, the work by Irwin (2002) represents a peer-reviewed publication in a leading economic journal and the quantitative methods are very well refined. In the absence of a study using the same methods and California data, Irwin's work represents the best rangeland open space study identified in the literature review. Note that work by Howard (2011) estimates the value of rangeland in Kern County California. However, his current work focuses on the economic theory underlying his approach and quantitative estimates are still a work in progress. Personal communication with Howard found that he felt the study by Irwin (2002), specifically a value of 2.6 percent change in home value, was consistent with his preliminary findings in California.

The study by Ready and Abdalla (2005) was identified as the most applicable for the value of intensive agricultural open space. Ready and Adballa estimate the positive and negative amenities from various types of agricultural open space in Pennsylvania. They use a revealed preference approach and analyze a comprehensive dataset on home sales, neighborhood characteristics, and proximity to open space. They identify the value (cost) of negative amenities such as noise, runoff, and pollution from Confined Animal Feeding Operations (CAFOs). They find that converting one acre of CAFO to urban development within one-third of a mile of the average home would increase its price by 6.4 percent (95 percent Confidence Interval (CI) = [3.2, 8.1]) on average.

There was a limited range of studies that estimated the negative amenity value of intensive agriculture. Mushroom farms, smaller scale livestock operations and, to a lesser extent, nurseries are the primary types of intensive agriculture in Santa Clara County expected to decrease nearby home values. The study by Ready and Abdalla (2005) focuses on CAFOs, which are used as a proxy for different types of intensive agriculture in Santa Clara. Although the study has a different geographic location, the results are based on robust economic analysis and represent defensible values for the negative value of intensive agriculture.

A.2.1. Summary of Results

The analysis focused on the value of an average parcel of agricultural open space. Valuation of all open space in the county would require collecting a comprehensive dataset of all agricultural and urban lands in a geospatial database. It would be necessary to know the location of every urban parcel relative to cropland, rangeland, or intensive agriculture. These areas are highlighted in yellow in Figure A1. It is beyond the scope of this study to identify the total number of parcels at the agriculture-urban interface in Santa Clara County.

Analysis of the literature shows that 0.25 mile proximity to agricultural cropland open space increases home values by 2.2 percent on average. Proximity to forests, rangeland, and native vegetation increases home values by 2.56 percent on average. Some open space provides negative value. Proximity within 0.33 mile of intensive agriculture decreases home values by 6.4 percent on average. Effects dissipate when homes are located farther away from the open space parcel. Table A1 summarizes the key findings of the analysis.

Table A1. Summary of Open Space Value

Land Use Type	Percent change in nearby home values for 1 parcel converted to open space	Radius (mi)	Study	Location
Cropland	2.20	0.25	Kuminoff (2009)	CA
Forests, rangeland	2.56	0.25	Ready and Abdalla (2005)	MD
Intensive agriculture	-6.40	0.3	Irwin (2002)	PA

A.2.2. Example Application

The value of converting an acre from urban to agricultural open space depends on the value of nearby homes. Morgan Hill, San Martin, and Gilroy are three cities closest to the agriculture-urban interface in Santa Clara County.

Consider conversion of 1 parcel from existing urban use to agricultural open space within 0.25 mile of an average home in the cities of Morgan Hill, San Martin and Gilroy. Table A2 summarizes the average change in home value in each location for three open space types. Column 2 lists the average home sale price as of May 2013 in each location. Average home sale prices are compiled from the Zillow Home Value Database and represent an average sale price for all homes sold between January and May 2013. Column 3 shows the change in the average home value if 1 parcel of urban development is converted to crop production. On average, home values increase by 2.2 percent, reflecting the implicit value of open space to the region. For example, in Gilroy this would increase the average value of homes located within 0.25 mile by $9,875. If the parcel was instead converted to rangeland the value would be $11,491. The average home value would decrease if the urban parcel was instead converted to intensive agriculture such as a mushroom farm. These changes in home values hold all other factors constant and consequently represent the implicit value of agricultural open space.

The net value will depend on the quantity and location of different agricultural open space. For example, if a single parcel, located within 0.25 mile of an average home in Gilroy, was converted from urban development to cropland and another parcel to intensive agriculture, home values near both parcels would decrease in value by 4.2 percent (2.2 - 6.4 percent), on average. The value of open space in this case is -$18,825 ($448,875 x 4.2%).

Table A2. Value of Open Space Example

		Change in home value due to conversion of 1 acre to:		
City	**Average Home Price***	**Cropland**	**Rangeland**	**Intensive**
Morgan Hill	$581,250	$12,788	$14,880	-$37,200
San Martin	$678,775	$14,933	$17,377	-$43,442
Gilroy	$448,875	$9,875	$11,491	-$28,728
Santa Clara County	$683,025	$15,027	$17,485	-$43,714

*Source: January 2013 - May 2013 average, computed from Zillow Home Value Database

It is important to note studies have shown that very close proximity to crop production actually decreases average home values. Although home values near cropland increase by 2.2% on average, for some homes situated directly adjacent to fields values actually decrease. A location too close to a productive field would expose the homeowner to negative amenities such as noise, pesticides, and other production externalities. This partially explains the prevalence of agricultural-urban buffer zones in many cities and emphasizes the importance of case-specific analysis.

A.3. Conclusion

The analysis clearly shows that there are positive effects on home values located in close proximity to agricultural open space. On average, home values increase by 2.2 - 2.56 percent when located close (within 0.25 mile) to cropland or rangeland. There are a few types of agriculture which could have negative effects from odors, noise, and other factors. In Santa Clara County these include mushroom farms and small-scale livestock operations. Proximity (within 0.33 mile) to intensive agriculture such as mushroom farms decreases home values by 6.4 percent on average as a result of negative amenities. Given the checkerboard development pattern in Santa Clara County and the limited amount of intensive agriculture open agricultural space contributes positive value to Santa Clara County.

A.4. Relevant Studies Reviewed

Anderson, Soren T., and Sarah E. West. 2006. “Open Space, Residential Property Values, and Spatial Context.” *Regional Science and Urban Economics* 36 (6) (November): 773–789. doi:10.1016/j.regsciurbeco.2006.03.007.

Brander, Luke M., and Mark J. Koetse. 2011. “The Value of Urban Open Space: Meta-analyses of Contingent Valuation and Hedonic Pricing Results.” *Journal of Environmental Management* 92 (10) (October): 2763–2773. doi:10.1016/j.jenvman.2011.06.019.

Geoghegan, Jacqueline, Lori Lynch, and Shawn Bucholtz. 2003. “Capitalization of Open Spaces into Housing Values and the Residential Property Tax Revenue Impacts of Agricultural Easement Programs.” *Agricultural and Resource Economics Review* 32 (1): 33–45.

Heimlich, Ralph E, and William D Anderson. 2001. “Development At The Urban Fringe And Beyond: Impacts On Agriculture And Rural Land”. Agricultural Economics Reports 33943. United States Department of Agriculture, Economic Research Service. http://ideas.repec.org/p/ags/uerser/33943.html.

Howard, Peter H. 2011. “Optimal Preservation of Agricultural and Environmental Land Within a Municipality Under Irreversibility and Uncertainty”. 2011 Annual Meeting, July 24-26, 2011, Pittsburgh, Pennsylvania 103639. Agricultural and Applied Economics Association. http://econpapers.repec.org/paper/agsaaea11/103639.htm.

Irwin, Elena G. 2002. “The Effects of Open Space on Residential Property Values.” *Land Economics* 78 (4) (November 1): 465–480. doi:10.2307/3146847.

Irwin, Elena G., and Nancy E. Bockstael. 2001. “The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Values.” *American Journal of Agricultural Economics* 83 (3) (August 1): 698–704. doi:10.2307/1245102.

Kotchen, Matthew J., and Shawn M. Powers. 2006. “Explaining the Appearance and Success of Voter Referenda for Open-space Conservation.” *Journal of Environmental Economics and Management* 52 (1) (July): 373–390. doi:10.1016/j.jeem.2006.02.003.

Kuminoff, Nicolai V. 2009. “Using a Bundled Amenity Model to Estimate the Value of Cropland Open Space and Determine an Optimal Buffer Zone.” *Journal of Agricultural and Resource Economics* 34 (1) (April 1): 68–90. doi:10.2307/41548402.

McConnell, Virginia D, and Margaret A Walls. 2005. *The Value of Open Space: Evidence from Studies of Nonmarket Benefits*. Resources for the Future Washington, DC. http://www.rff.org/RFF/Documents/RFF-REPORT-Open%20Spaces.pdf.

Ready, Richard C., and Charles W. Abdalla. 2005. “The Amenity and Disamenity Impacts of Agriculture: Estimates from a Hedonic Pricing Model.” *American Journal of Agricultural Economics* 87 (2) (May 1): 314–326. doi:10.1111/j.1467-8276.2005.00724.x.

Sokolow, Alvin D, and Cathy Lemp. 2002. “Agricultural Easement Programs . . . Saving Agriculture or Saving the Environment?” *California Agriculture* 56 (1) (January 1). https://vpn.lib.ucdavis.edu/uc/item/,DanaInfo=escholarship.ucop.edu+89n824ct.

Technical Appendix B: Ecosystem Service Value

This technical appendix provides an independent and quantitative assessment of the value of ecosystem services provided by agriculture in Santa Clara County using a comprehensive literature review and meta-analysis.

Agricultural land provides ecosystem services to the surrounding region in the form of hydrological services, carbon sequestration, increased biodiversity and habitat preservation for flora and fauna. The District encourages preservation of open space through the Open Space Credit, which essentially functions as an agricultural irrigation water subsidy to encourage agricultural lands in the county.

Open space and agricultural land in Santa Clara County includes rangeland, land in conservation easements, and native vegetation, in addition to intensive agriculture and crop production. The analysis in this appendix includes a comprehensive review of the economic and ecological literature on the value of ecosystem services provided by these land uses and identifies studies that are most applicable to Santa Clara County. Relevant studies are used to provide a range of estimates for the value of ecosystem services provided by agricultural land within the county.

B.1. Ecosystem Services

Ecosystem services can be broadly defined as the amenities provided by resources and natural systems. Services include maintenance of soil quality, species habitat, clean drinking water, and a general existence value through support provided to a larger ecosystem network. Ecologists have identified over one hundred ecosystem services that can be associated with agriculture and open space. Most services are location-specific such as habitat for local species. This technical appendix considers seven common ecosystem services provided by agriculture and specific attention is paid to flood control and groundwater recharge.

Scientists have long recognized the importance of ecosystems but the economic value of these services has only recently attracted attention. The United Nations commissioned the Millennium Ecosystem Assessment (MEA) in the year 2000 to “assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being.” The MEA included contributions from over 2,000 scientists. The report identified the following four categories of ecosystem services:

- *Provisioning services* – Products provided by the ecosystem.
    - *Examples*: Food, timber, fiber, biochemicals, pharmaceuticals, water.
- *Regulating services* – Processes that are regulated by the ecosystem.
    - *Examples*: Carbon sequestration, flood control, water recharge, water quality.
- *Cultural services* – Intangible existence value of the ecosystem.
    - *Examples*: Recreation opportunities, aesthetic value, spiritual benefits.
- *Supporting services* – The ecosystem as part of a broader natural process.
    - Examples: Soil formation, photosynthesis, nutrient cycling.

Services provided by agriculture typically fall into the provisioning and regulating categories listed above. Primary provisioning services include the food value of crops produced on the land. Regulating services include a range of benefits such as flood control, groundwater recharge, erosion control, pollination, and provision of habitat, to name a few. This technical appendix will review the range of common ecosystem services provided by agriculture and will focus particularly on flood control and groundwater recharge.

B.1.1. Methods for Estimating the Value of Ecosystem Services

Economic valuation of ecosystem services stems from an interest in using ecosystems to augment engineered control projects. Wetlands can provide flood control and water quality benefits, which can also augment existing levees or water treatment plants. The first attempts to value ecosystem services come from Daily et al. (1997) and Costanza et al. (1997). Daily and Costanza and co-authors attempted to estimate the total value of services provided by global ecosystems using a variety of new methodologies. They estimated the total value of global ecosystem services to fall in the range of $16–54 trillion per year. Although this work has since been recognized as a rough approximation, it did serve to stimulate a large body of research and policy reports attempting to value ecosystem services.

Many ecosystem services are non-market goods in that they are not actively traded in a market with an observed price. Further complicating the problem, the appropriate geographic scale for analysis varies widely as some services are local in nature, such as pollination, while others are global, such as carbon sequestration. Even with a well defined geographic scale the valuation of services remains location dependent. For example, soil factors (organic matter, texture and sediment profile), climatic factors (solar radiation, precipitation, temperature) and naturally occurring flora and fauna can affect the value of an ecosystem service. The fact that management practices can have a significant effect on the level of ecosystem services produced also adds to the complexity of valuing these services. Organic and conventional agriculture have different effects on the ecosystem, and consequently the ecosystem service values associated with the two production processes vary greatly. Applied policy research and the academic literature continue to develop new methods to value ecosystem services.

The total value of ecosystem services equals to the sum of all of the individual services provided. Services for agriculture may include flood control, erosion control, water quality, food production, crop biodiversity, and biological control, among others. Each individual service requires a different valuation approach and must be considered on a case-by-case basis.

The value of individual ecosystem services can be classified as market or non-market. Market values are those for which the value is directly observable in a market through prices. For example, crops grown on the land provide a direct value for food on the market. Non-market values include those for which no market exists. For example, the habitat value of agricultural land as a hunting ground for predatory bird species is not traded in the market. Swinton et al. (2007) identify four common methods used to estimate the non-market values of ecosystem services.

- Contingent valuation
    - Using the market price of farmland and surrounding properties to infer the value of non-market attributes
- Stated preference methods
    - Conducting surveys to identify individuals willingness-to-pay for services
- Avoided cost methods
    - Assessing flood risk with and without agricultural lands present to infer the value of agriculture for flood control
- Approaches based on cost of mitigation or replacement of resources with other sources

- Removal of wetlands may require building an additional water treatment facility which has an observable cost

Studies determine appropriate valuation methods by considering the ecosystem services of interest and the geographic scale. It is important to note that measurement and valuation in the context of agricultural ecosystems remain a work in progress.

B.2. Ecosystem Services Related to Agriculture

Groundwater management and flood control are part of the District's mission. In addition to groundwater recharge and flood control, an additional five services commonly associated with agricultural production were identified. Ecosystem service values provided by agriculture in Santa Clara County include flood control, groundwater recharge, water quality, pollination, habitat, biodiversity and nitrogen regulation.

Flood control. Agriculture can provide a natural buffer for variation in seasonal water flows and rainfall. Land management practices up and downstream affect runoff, drainage and the frequency of flood events. In some areas agriculture can be managed for both crop production and as a seasonal floodplain. Agriculture typically has a lower cost for a given level of flood risk than residential and commercial development.

Groundwater recharge. Deep percolation from irrigation and precipitation will result from some portion of applied water in excess of consumptive use. This proportion depends on field soil characteristics, slope, crop type and irrigation practices.

Water quality. Surface runoff and deep percolation of water from irrigation and precipitation on agricultural land can increase or decrease water quality. Excessive nitrogen application can lead to significantly decreased water quality. Less intensive agriculture such as rangeland can provide a natural filter for water.

Pollination. Wild pollinator populations have recently been on steady decline in California. Agriculture provides natural habitat for pollinators.

Habitat. Conversion from native vegetation to agriculture can destroy habitat for some species. However species such as the Swainson's Hawk and other predatory birds benefit from hunting conditions on open fields.

Biodiversity. A diverse crop mix and rotation system functions as a natural break for pest and disease cycles. It also provides flexibility for producers to respond to changes in agricultural prices and import and export market conditions.

Nitrogen regulation. Excessive nutrient runoff is a primary cause of eutrophication of surface water. Agriculture is a primary contributor to this problem in many regions, although rotation systems and other field management decisions can be used to manage nitrogen application and reduce runoff.

Agriculture creates a unique ecosystem that benefits from and creates services at the same time it provides many disservices. The cost of ecosystem disservices from agriculture should not be understated. For example in the Llagas Subbasin, the rate of domestic well contamination above the nitrate MCL is rather high, and the primary cause is fertilizers used in agriculture followed by septic tanks. This analysis focuses on the value of ecosystem services, but careful attention should be paid to tradeoffs between the benefits described and potential costs along other dimensions.

B.3. Meta-Analysis of Ecosystem Service Value

Despite the fact that measuring and valuing ecosystem services from agriculture is a new field of research many studies have been able to produce quantitative estimates of service levels and their associated values. Several dozen studies were reviewed and 22 were identified as relevant for Santa Clara County. From these, 4 studies were identified for use in the meta-analysis. The decision to include the study in the meta-analysis was based on three criteria:

- The study estimates some or all of the 7 ecosystem service values for agriculture
- The study used data from a region with a large agriculture-urban interface similar to that in Santa Clara County.
- The study was peer-reviewed or part of a public report that was based on peer-reviewed publications.

Studies included in the meta-analysis include Chan et al. (2006), Sandhu et al. (2008), Porter et al. (2009) and Costanza et al. (1997).

Chan et al. (2006) represents the work most relevant to Santa Clara County. The authors model the level of six different ecosystem services including carbon storage, flood control, forage production, outdoor recreation, crop pollination and water provision for the Central Coast region of California. The geographic scope of their analysis includes parts of Santa Clara County. Their analysis relies on previous estimates of the value of specific ecosystem services which they incorporate into a spatial economic-ecologic model of the Central Coast region. They are particularly interested in examining the spatial correlation between various types of services. Spatial correlation between ecosystem services is not relevant for this analysis but the values used in their study are applicable to the Central Coast region including portions of Santa Clara County.

Sandhu et al. (2008) design an experimental approach to measure the economic value of ecosystem services under conventional and organic arable systems in the Canterbury region of New Zealand. This region of New Zealand lacks the level of agriculture-urban interface found in Santa Clara County, however the methods and results in this study are informative for aggregate ecosystem service value estimates. The authors estimate the value of all ecosystem services provided by conventional and organic agriculture and this includes the seven services identified as relevant for Santa Clara. Some of the services they value include biological pest control, soil formation, mineralization of plant nutrients, pollination, services provided by shrubs/hedges, hydrological flow, aesthetics, carbon sequestration, nitrogen fixation and soil fertility. The authors find that the total value of all ecosystem services ranges between $651 and $7,862 per acre per year for organic fields and $514 to $5,898 per acre per year for conventional fields. This study is used to provide a bound on the range of the value of ecosystem services in Santa Clara County.

Porter et al. (2009) estimate the value of ecosystem services produced by an experimental organic agro-ecosystem in Denmark that simultaneously produces food, fodder and bio-energy. They use an experimental design approach similar to that used by Sandhu et al. (2008). The authors focus on identifying non-market benefits related to ecosystem services provided by agriculture, in contrast to Sandhu et al. who focused on total benefits (market plus non-market values). They estimate the value of non-market ecosystem services to range from $196–$372 per acre per year, depending on the crop and management practices.

Costanza et al. (1997) estimate the total value of global ecosystem services using various methods. The data in the study are not specific to Santa Clara County, however the authors provide defensible estimates of a range of services related to agriculture and these estimates are used to validate the estimates from the studies discussed above. In some cases the values in Costanza et al. (1997) are used to provide upper and lower bounds for estimates from other studies.

B.3.1. Summary of Meta-Analysis Results

Key ecosystem services that would be affected by changes in the acreage of irrigated agriculture in Santa Clara County are summarized in Table B1. Values vary by service type from negative (ecosystem disservices) to over $400 per acre. The two areas of particular interest for this study include groundwater recharge and flood control.

Table B1 summarizes total ecosystem service values. Flood control total ecosystem service values are between $42 and $86 per acre. The value of flood control ecosystem services is typically estimated using an avoided cost approach. In the avoided cost framework the estimated value of an agricultural acre for flood control benefits is based on the change in risk and additional cost of flood events if the land were converted to urban use. These values are based on results from analysis by Porter et al. (2009), described above, and validated with results from Costanza et al. (1997). Values in Santa Clara County are likely to be higher given the high-value urban land in North County, and significant agriculture-urban interface in South County.

Groundwater recharge total ecosystem service values are between $22 and $44 per acre. Groundwater recharge benefits are estimated using a soil-water balance approach and include the benefits from irrigation water and precipitation deep percolation. Irrigation and precipitation in excess of consumptive use goes to soil capacity, surface runoff, or deep percolation. Studies reviewed for the meta-analysis typically make location specific adjustments for the proportion of soil capacity and surface runoff in order to estimate the amount of groundwater recharge provided by an average acre. The meta-analysis relies on results by Sandhu et al. (2008) and Costanza et al. (1997), described above. This estimate is a lower bound and is further refined in the following sections.

Table B1. Meta-Analysis of the Total Value of Ecosystem Services Provided by Agriculture

Service	Total Value ($/ac)	Summary Notes
Flood Control	$42 – $86	*Santa Clara County is likely at or above the high end of this range due to North County flood control requirements.*
Groundwater Recharge	$22 – $44	*This value represents the average for direct recharge from irrigation and precipitation. Santa Clara County has a higher value and this estimate is further refined.*
Water Quality	$27	*Value represents an average, range varies from positive to negative depending on the crop.*
Pollination	$19 – $64	*None.*
Habitat	Varies	*Estimates are both crop and species-specific. Excluded from this analysis.*
Biodiversity	$31	*None.*
Nitrogen Regulation	$0 – $433	*Estimates are crop-specific and can be negative in some cases.*

Table Notes: Compiled as part of a meta-analysis using estimates from Costanza et al. (1997), Sandhu et al. (2008), Porter et al. (2009), and Chan et al. (2009).

Many of the studies used for this meta-analysis break-down the ecosystem service values into market and non-market components. Market values include the avoided cost of increased risk and deep percolation of groundwater from irrigation and precipitation for flood control and groundwater recharge, respectively. Non-market values for flood control include upstream and downstream effects of changes in land use that change the frequency of flood events. Non-market values for groundwater recharge include factors such as the effects of field-specific management decisions on the proportion of irrigation and precipitation that results in deep percolation. A weighted average over all studies reviewed shows that non-market and market value are approximately 67 and 33 percent of the total value on average, respectively.

Ecosystem service values are location and crop-specific. The values reported in Table B1 should be interpreted as average representative values of an average acre of agricultural land. More refined estimates would require more detailed analysis and data collection for Santa Clara County.

The following section includes suggestions for a county-specific analysis and provides an estimate of the value of groundwater recharge.

B.4. Santa Clara County Framework

While a full empirical measurement of benefits of groundwater recharge and flood control from agricultural production in Santa Clara County is beyond the scope of this study, and definitely beyond the current empirical database, the following discussion of how to approach such a measurement will be useful in applying the meta-analysis summarized in the previous section.

B.4.1. Flood Control

There are two broad approaches to characterize flood control; (i) it can be characterized as dispersion on a floodplain, or (ii) channelization between levees. Economic analysis of flood control increasingly reinforces the conclusion that channeling floods through levees changes their location but that ultimately both the water and the energy have to be dissipated by a diffusion process. Increasingly the high fiscal and environmental cost of building improved levees has caused flood control engineers to reconsider the use of floodplains as a major part of flood control. Wetlands and agricultural land can provide a valuable ecosystem service to support flood control.

Consider Yolo and Sacramento County as a case study of the interaction between agriculture and flood control. Sacramento River flood control is achieved through a combination of levees and floodplains. In particular, the Yolo Bypass floodplain was designed to reroute Sacramento River water around the greater Sacramento urban area. The establishment of irrigated agriculture and flood easements throughout the floodplain has ensured a functioning bypass. Field preparation by growers during the spring and summer removes debris and vegetation from the bypass, thereby ensuring that potential flooding stays within the desired area in the following season. This is a non-market flood control ecosystem service value provided by agricultural lands in the Yolo Bypass.

The main difficulty in using agricultural land for floodplains in Santa Clara County is that there are limited opportunities in North County due to the limited amount of agricultural land, particularly on the valley floor. The areas of agriculture able to accommodate periodic flooding are concentrated in South County, specifically the Coyote Valley and Llagas sub-basins. A quantitative assessment of benefits of maintaining the land in the Coyote Valley and Llagas sub-basins would require careful analysis of existing flood risk areas and their associated watersheds. This information can then be used to assess target areas for purchase of flood easements and, in turn, value the associated flood control ecosystem service in Santa Clara County.

B.4.2. Groundwater Recharge

Field management decisions control the proportion of irrigation and precipitation for evapotranspiration, surface runoff, and groundwater recharge. Studies including Schilling et al. (2010) have shown that land converted from native vegetation to annual crops can increase groundwater recharge. Irrigated agriculture provides groundwater recharge from two key sources:

- Deep percolation of water applied for crop irrigation.
- Deep percolation during times when precipitation exceeds evapotranspiration.

This analysis considers a set of calculations to assess a realistic range from natural recharge in the agricultural areas in Santa Clara County. The analysis combines seasonal values of evapotranspiration, applied water requirements, total irrigated acres by crop, and irrigation efficiency in Santa Clara County. Land use data are from the Santa Clara Valley Water District Agricultural Production Model, prepared under a separate Task in this project, and water data are compiled from the California Department of Water Resources reports for Santa Clara County. Table B2 summarizes Santa Clara water use data for 10 key crop groups.

Table B2. Land and Water Use Summary Data

Data	Units	Alfalfa	Fruit and Nuts	Field Crops	Processing Tomatoes	Fresh Tomatoes
Acreage	ac	378	1,154	833	1,035	759
Applied Water	af/ac	3.35	2.82	1.83	2.25	1.88
Evapotranspiration	af/ac	3.40	2.90	2.60	2.00	1.60
Effective Precipitation	af/ac	0.65	0.62	1.13	0.20	0.10
Evapotranspiration of Applied Water	af/ac	2.75	2.29	1.47	1.80	1.50
Consumed Fraction	%	0.82	0.81	0.80	0.80	0.80

Data	Units	Pasture	Vegetables	Cucurbits	Onions and Garlic	Grapes
Acreage	ac	468	7,995	970	538	1,540
Applied Water	af/ac	3.70	2.50	1.33	2.88	1.29
Evapotranspiration	af/ac	3.50	2.47	1.10	2.50	1.60
Effective Precipitation	af/ac	0.50	0.47	0.04	0.20	0.57
Evapotranspiration of Applied Water	af/ac	3.00	2.00	1.06	2.30	1.03
Consumed Fraction	%	0.81	0.80	0.80	0.80	0.80

Source: Land use data compiled by authors, water use data from CA Department of Water Resources.

In addition to applied irrigation water, agricultural land may provide recharge through deep percolation when precipitation exceeds evapotranspiration. Table B3 summarizes average monthly rainfall in inches using a 1990-2003 average from the Gilroy (D10 3417 00) weather station. Rainfall data are available for a longer historical time series, 1990 – 2003 are selected as a representative subset of years covering dry years in the early 1990's in addition to wet and average water years.

Table B3. 1990-2003 Average Monthly Rainfall at Gilroy, California (inches)

	Oct	Nov	Dec	Jan	Feb	Mar
Precipitation (in)	0.819	2.068	3.336	5.491	4.266	2.981

	Apr	May	Jun	Jul	Aug	Sep
Precipitation (in)	0.906	0.756	0.096	0.008	0.064	0.078

These data can be used to apply a soil-water balance approach to estimate the net recharge to Santa Clara County groundwater provided by agriculture. Agriculture for this analysis includes 15,760 acres of irrigated land detailed in table B2 plus an additional 3,650 acres of dry farmed hay grain for a total of 19,410 acres. Rangeland acreage (just over 210,000 acres) are excluded from this analysis. Deep percolation can be defined as:

- Deep percolation = precipitation + irrigation - soil storage - surface runoff - evapotranspiration.

This analysis considers a monthly time-step for the above equation. Surface runoff is assumed constant at zero for all months. In practice a limited amount of surface runoff is likely and this would decrease groundwater recharge value estimates provided below. Monthly precipitation is from Table B3 and converted to acre feet per acre. Monthly evapotranspiration for each crop is calculated by proportionally allocating the values reported in table B2 across the growing season for each crop. Monthly evapotranspiration of idle fields (non-growing season for each crop) varies from 0.07 to 1.1 inches, using data from Zone 9 (includes most of Santa Clara) estimated by the California Department of Water Resources and the Irrigation Training and Research Center at Cal Poly San Luis Obispo. Growers are assumed to optimize irrigation. During the growing season irrigation water is never applied in excess of evapotranspiration minus precipitation. Change in soil storage each month depends on field capacity for which data are not readily available for use in this analysis. Therefore two scenarios are considered, (i) an upper bound where the soil is assumed always at field capacity, and (ii) a lower scenario where the soil is only at field capacity in the winter and early spring months (December - March). In months where the field is below soil capacity deep percolation is zero.

Table B4 summarizes the results of the analysis. Groundwater recharge is estimated between 10,686 and 13,140 acre-feet per year. This translates into an average 0.55 to 0.68 acre-feet of groundwater recharge provided by an acre of dry farmed hay grain plus irrigated agricultural land in Santa Clara County. The average cost of an acre foot of agricultural water to the District is $246 per acre-foot (as of Fiscal Year 2014) and this is used to value the groundwater recharge. A cost of $246 per acre foot of agricultural water and recharge between 0.55 and 0.68 acre-feet per acre implies a groundwater recharge ecosystem service value between $135.30 and $167.28 per acre per year.

Table B4. Groundwater Recharge Ecosystem Service Value in Santa Clara County

Scenario	Groundwater recharge (af/year)	Acre-feet per acre per year	Value per af ($/af)	Groundwater Recharge Value ($/ac per year)
Field capacity only in winter months	10,686	0.55	$246	$135.30
Always at field capacity	13,140	0.68	$246	$167.28

Note that changes in factors omitted from the analysis such as permeability, field capacity, and storability, as well as the time needed for deep percolation can change the estimated value. However, assumptions may increase or decrease the value and, on balance and when compared to the meta-analysis results, these estimates suggest a positive value for groundwater recharge. These initial calculations suggest that the benefits of groundwater recharge associated with agricultural lands in Santa Clara County groundwater basins offset a portion of the cost of recharging water pumped by the agricultural sector.

B.4.3. Summary

Analysis of flood control and groundwater recharge benefits suggests that opportunities exist to increase the role of agriculture in flood control in Santa Clara County and that the effect of agriculture on recharge in the groundwater basin is significant and appears to justify some of the special treatment that Santa Clara County agriculture receives through the open space credit program. Groundwater benefits may also warrant additional hydrologic analysis in order to refine the analysis in this report, which was calculated using standard parameters applied to the entire county agricultural sector. The District's existing groundwater models are tools that could be used for the hydrologic analysis.

B.5. Conclusion

Ecosystem services are difficult to define and challenging to value. Work continues to develop the scientific methodologies to understand ecosystem processes and the economic approaches to value individual components. With this in mind, this study has presented results of a literature review and meta-analysis based on a comprehensive literature review of ecosystem service valuation studies. Particular attention was paid to groundwater recharge and flood control benefits. Five additional services commonly attributed to agriculture were presented to provide context for groundwater recharge and flood control benefits.

Taking the meta-analysis results for the value of flood control benefits presented in table 4 and the groundwater recharge estimates presented in table 5, the estimated total value of groundwater recharge and flood control ecosystem services provided by agriculture to Santa Clara County is between $177.30 and $253.28 per acre per year.

Note that these values are contingent on a number of assumptions and location specific factors should be factored into specific policy decisions. It is additionally important to consider land use conversion. When analyzing the provision of ecosystem services, it is necessary to consider changes from one type of land use to another. For example, conversion from irrigated agriculture to wetlands or urban development will lead to changes in ecosystem service values.

B.6. Relevant Studies Reviewed

Boyd, James, and Spencer Banzhaf. 2007. “What Are Ecosystem Services? The Need for Standardized Environmental Accounting Units.” *Ecological Economics* 63 (2–3) (August 1): 616–626. doi:10.1016/j.ecolecon.2007.01.002.

Brouwer, Roy, and Louis H. G. Slangen. 1998. “Contingent Valuation of the Public Benefits of Agricultural Wildlife Management: The Case of Dutchpeat Meadow Land.” *European Review of Agricultural Economics* 25 (1) (January 1): 53–72. doi:10.1093/erae/25.1.53.

Brown, Thomas C, John C Bergstrom, and John B Loomis. 2007. “Defining, Valuing and Providing Ecosystem Goods and Services.” *Natural Resources Journal* 47 (2): 329–376.

Chan, Kai M. A, M. Rebecca Shaw, David R Cameron, Emma C Underwood, and Gretchen C Daily. 2006. “Conservation Planning for Ecosystem Services.” *PLoS Biol* 4 (11) (October 31): e379. doi:10.1371/journal.pbio.0040379.

Colombo, Sergio, Javier Calatrava-Requena, and Nick Hanley. 2006. “Analysing the Social Benefits of Soil Conservation Measures Using Stated Preference Methods.” *Ecological Economics* 58 (4) (July): 850–861. doi:10.1016/j.ecolecon.2005.09.010.

Costanza, Robert, Ralph d’ Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, et al. 1997. “The Value of the World’s Ecosystem Services and Natural Capital” 387 (6630) (May 15): 253. doi:10.1038/387253a0.

Daily, Gretchen, Susan Alexander, Paul R. Erlich, Larry Goulder, Jane Lubchenco, Pamela A. Matson, and Harold A. Mooney. 1997. “Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems.” *Washington (DC): Ecological Society of America* 2.

De Groot, Rudolf S, Matthew A Wilson, and Roelof M.J Boumans. 2002. “A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services.” *Ecological Economics* 41 (3) (June): 393–408. doi:10.1016/S0921-8009(02)00089-7.

Heal, Geoffrey M., and Arthur A. Small. 2002. “Chapter 25 Agriculture and Ecosystem Services.” In *Handbook of Agricultural Economics*, 2:1341. Elsevier. https://vpn.lib.ucdavis.edu/science/article/pii/,DanaInfo=www.sciencedirect.com+S1574007202100077.

Kroeger, Timm, and Frank Casey. 2007. “An Assessment of Market-based Approaches to Providing Ecosystem Services on Agricultural Lands.” *Ecological Economics* 64 (2) (December 15): 321–332. doi:10.1016/j.ecolecon.2007.07.021.

MEA. 2005. “Ecosystems and Human Well-being: Synthesis.” Millenium Ecosystem Assessment. Washington, D.C.

Montagnini, Florencia. 2005. *Environmental Services of Agroforestry Systems*. Psychology Press.

National Academy of Sciences. 2004. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. http://www.nap.edu/catalog.php?record_id=11139.

Nelson, Erik, Guillermo Mendoza, James Regetz, Stephen Polasky, Heather Tallis, Drichard Cameron, Kai MA Chan, et al. 2009. “Modeling Multiple Ecosystem Services, Biodiversity Conservation, Commodity Production, and Tradeoffs at Landscape Scales.” *Frontiers in Ecology and the Environment* 7 (1) (February): 4–11. doi:10.1890/080023.

Porter, John, Robert Costanza, Harpinder Sandhu, Lene Sigsgaard, and Steve Wratten. 2009. “The Value of Producing Food, Energy, and Ecosystem Services Within an Agro-ecosystem.” *Ambio* 38 (4) (June): 186–193.

Power, A. G. 2010. “Ecosystem Services and Agriculture: Tradeoffs and Synergies.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 365 (1554) (August 16): 2959–2971. doi:10.1098/rstb.2010.0143.

Sandhu, Harpinder S., Stephen D. Wratten, Ross Cullen, and Brad Case. 2008. “The Future of Farming: The Value of Ecosystem Services in Conventional and Organic Arable Land. An Experimental Approach.” *Ecological Economics* 64 (4) (February): 835–848. doi:10.1016/j.ecolecon.2007.05.007.

Schroth, Goetz, Gustavo A. B. da Fonseca, and Celia A. Harvey. 2004. *Agroforestry and Biodiversity Conservation in Tropical Landscapes*. Island Press.

Schroth, Götz, and Fergus L. Sinclair. 2003. *Trees, Crops, and Soil Fertility [electronic Resource]: Concepts and Research Methods*. CABI.

Schilling, K.E., K.S. Chan, H. Liu, and Y.K. Zhang. 2010. "Quantifying the effect of land use land cover change on increasing discharge in the upper Mississippi River." *Journal of Hydrology*. 387:343-345.

Swinton, Scott M., Frank Lupi, G. Philip Robertson, and Stephen K. Hamilton. 2007. “Ecosystem Services and Agriculture: Cultivating Agricultural Ecosystems for Diverse Benefits.” *Ecological Economics* 64 (2) (December): 245–252. doi:10.1016/j.ecolecon.2007.09.020.

Wood, Stanley, Kate Sebastian, Sara J. Scherr, and Niels H. Batjes. 2000. *Agroecosystems*. World Resources Institute.

Wossink, Ada, and Scott M. Swinton. 2007. “Jointness in Production and Farmers’ Willingness to Supply Non-marketed Ecosystem Services.” *Ecological Economics* 64 (2) (December 15): 297–304. doi:10.1016/j.ecolecon.2007.07.003.

Technical Appendix C: Model Documentation

This technical appendix provides an overview of the economic model developed to analyze the direct economic impacts to growers from changes in the agricultural groundwater charge.

The ability to analyze changes in the groundwater charge under short run and long run conditions requires an economic model of the agricultural economy in Santa Clara County which is able to reflect the incremental effects of changes in water costs. Changes in local economic activity occur gradually as costs and benefits change, so there is a corresponding difference between short run and long run analysis. Grower response to increasing groundwater charges will be a smooth adjustment, rather than a sudden shift out of production.

The analysis relies on an economic evaluation framework known as a calibrated optimization model. The model calibrates to an observed set of base years using observed grower decisions and economic data. The framework used to analyze changes in the agricultural groundwater charge is grounded in observed data and economic principles and represents the incremental adjustments by growers in response to changing production costs.

C.1. Problem Overview

The Open Space Credit essentially functions as a groundwater charge subsidy for agricultural users. The District currently charges agricultural groundwater users between 3 and 6 percent of the corresponding Municipal and Industrial (M&I) rates. The District has requested an economic analysis of the impact of higher groundwater charges on agricultural users in Santa Clara County.

Changes in the cost of irrigation water may alter the crop mix in the short and long run. In addition to impacts on open space, this may have financial implications for the District and Santa Clara County. The District has requested analysis of two alternative scenarios where agricultural groundwater charges are increased to 10% or 25% of M&I water rates by fiscal year 2024. The scenarios include a 10 year phase in period starting in fiscal year 2015 and are compared relative to projected baseline agricultural groundwater charges.

Economic analysis of increased agricultural groundwater charges consists of three key components, (i) grower response within the region through a shift in crop mix, (ii) grower response through an increase in land fallowing, and (iii) increased costs of production for all growers.

C.2. Santa Clara County Agricultural Model Objectives

The agricultural economic model developed for this study will be referred to as the Santa Clara County model. The model is used to estimate changes in county agriculture as a result of changes in the District's groundwater charge. Other factors such as relative crop prices, market conditions, and other input costs are held constant in order to isolate the effect of changes in the groundwater change. The analysis considers direct impacts to growers including input use (i.e., land, labor, water, other supplies), revenue, and costs under three (3) scenarios defined by the District.

The following are considered for the analysis:

- Scenarios considered: Baseline, groundwater charge gradually increased to 10% of M&I over a 10-year horizon, and groundwater charge gradually increased to 25% of M&I over a 10-year horizon.
- Time frames considered: All scenarios are evaluated over a 10 year time frame from fiscal year 2015 to fiscal year 2024.
- The model holds other input costs, crop prices, resource availability, and market conditions constant to isolate the effect of changes in the groundwater charge.

- Relevant impacts include changes in input use, revenues, and costs by crop and region.
- Mushroom farms and nurseries are modeled separately from standard crop production.

The direct economic cost to growers from changes in the agricultural groundwater charge is defined as the difference between the baseline scenario and the 10 percent and 25 percent scenarios, respectively.

The analysis considers direct economic impacts across four dimensions:

- Shifts in the regional crop mix
- The decision to fallow (non-rotational) land
- Increased groundwater cost to all growers
- Cost to mushroom farms and nurseries (treated separate from the model)

The sum of these individual components equals the incremental direct cost to growers at any point in time. The total cost can be calculated by discounting the 10 year stream of costs back to the present plus the infinite future stream beginning in year 11 onward. This analysis only considers the direct cost to growers and does not include upstream and downstream costs to markets that support, and are supported by agriculture.

C.3. Santa Clara County Model Overview

The Santa Clara County model is a regional agricultural production and economic optimization model that simulates the decisions of growers across agricultural land in Santa Clara County. Similar models have been used for numerous policy analyses and impact studies since the 1980's, by agencies including the California Department of Water Resources, United States Fish and Wildlife Service, Unites States Army Corps of Engineers, and United States Bureau of Reclamation. This model framework has additionally been applied for a range of water districts and counties and is currently being used to evaluate alternatives in the Bay Delta Conservation Plan.

The model assumes that growers attempt to maximize profits[2] by choosing total input use (for example, total crop acres), but are subject to constraints and conditions on resource availability, land suitability, input costs, and markets. Input use intensity (for example, applied water per acre) is held constant in the Santa Clara County model. Growers face competitive markets, where no one grower can influence crop prices. The competitive market is simulated by maximizing grower profits (sometimes referred to as producer surplus) subject to the following relationships and constraints:

- Leontief (fixed proportion) production functions for every crop in every region.
    - A production function is a mathematical relationship that translates input use (land, labor, water, other supplies) into agricultural production (yield).
    - The Leontief production function is a specification that holds input use intensity constant. In other words, labor, water, and other supply input use per acre is held constant across all scenarios.
    - There are 4 inputs including land, labor, water, and other supplies.

---

[2] Profit is defined as returns to land, management, and risk. Profit = Crop revenue (price x yield x acres, by crop and region) - water costs - other production costs (excluding land)

  - Parameters are calculated using a combination of observed grower decisions and economic data and the method of Positive Mathematical Programming, discussed in the following section.
- Incremental land cost functions, estimated using the method of Positive Mathematical Programming. These cost functions capture the increasing cost of bringing additional land into production, by using observed grower land use and acreage response elasticities which relate change in acreage to changes in expected returns and other information.
- Groundwater pumping cost including depth to groundwater, energy cost, and District groundwater charge for each region.
- Resource constraints on land, labor, water, and other supplies availability.
- Agronomic and economic constraints on perennial crop acreage changes and crop rotations.

The model chooses the optimal values of land, water, labor, and other input use subject to the above constraints and definitions. For this project, the model is then used to compare the response of agriculture in Santa Clara County to potential changes in the agricultural groundwater charge. The model framework can estimate grower response to a range of additional policies including, for example, changes in crop prices, water availability, energy costs, or other input costs and availability.

C.3.1. Model Calibration

The Santa Clara County model self-calibrates using a three-step procedure based on the method of Positive Mathematical Programming (PMP) and the assumption that farmers behave as profit-maximizing agents. The method of PMP has been used by economists since the early 1980's and was formalized in a publication by Howitt (1995). The essence of PMP can be described as follows. In a traditional optimization model profit-maximizing growers would simply allocate all land, up until resource constraints become binding, to the most valuable crop(s). In practice, regions such as Santa Clara County exhibit a diverse mix of crops, some of which are relatively low-value. PMP incorporates information on the marginal production conditions that farmers face, allowing the model to calibrate to a base year of observed input use and output. Marginal conditions may include inter-temporal effects of crop rotation, proximity to processing facilities, management skills, farm-level effects such as risk and input smoothing, and variation in soil and other field conditions.

PMP translates unobservable marginal conditions using observed grower decisions and economic data in the form of acreage response elasticities. This information is represented as a crop and region specific cost function which allows the model to calibrate to a base year of observed input use and output.

PMP, as it is applied to the Santa Clara County model, is fundamentally a three step procedure, although each step includes a number of calculations and model checks.

1. The first step in PMP is a linear program of farm profit maximization subject to resource constraints, with calibration constraints set to observed values of land use. The resource and calibration constraints contain information on the value of additional resources (e.g. land and water) and the marginal opportunity cost of restricting valuable activities in order to bring what appear to be less-profitable activities into the optimal solution.

2. The information from the calibration and resource constraints is used in a second step to calibrate exponential PMP land cost functions and Leontief production functions.

3. The third step is a non-linear farm profit maximization program that includes the calibrated PMP cost functions and Leontief production functions. The calibrated cost functions guarantee that the program calibrate to observed data (in inputs and output) without restrictive calibration constraints.

4. Policy analysis follows in subsequent model scenarios by changing relevant parameters such as the groundwater charge, input costs, output prices, or resource constraints.

C.3.2. Model Validation

The Santa Clara County model, and calibration by PMP, uses a sequential testing process for model validation, diagnosing problems, and debugging the model. At each stage in the model there is a corresponding model check.

C.4. Santa Clara County Model Components

The following section reviews the key components and data in the Santa Clara model and how they are incorporated.

C.4.1. Crops

The model includes 18 representative crop groups, excluding mushroom farms and nurseries which are treated separately. Crop groups are the same across all model regions. Each group can represent a number of individual crops, but most are dominated by a single crop in Santa Clara County. Harvested acreage represents acreage of all crops within each group, and production costs and returns are represented by a single proxy crop. Proxy crops for each group were chosen based on standard criteria applied to similar economic models:

- A detailed crop budget was available.
- It is the largest acreage within the group.
- Its water requirement is representative of all crops in the group.
- Gross and net returns are representative of all crops in the group.

The relative importance of the selection criteria varies by crop group. Table C1 summarizes the crop groups and corresponding proxy crop.

Table C1. Santa Clara County Model Crop Groups

Model Definition	Proxy Crop	Other Crops
Alfalfa	Alfalfa Hay	
Apricot	Apricot	
Beans	Dry Beans	Lima Beans
Cherries	Cherries	
Citrus	Olives	Misc. Citrus
Cucurbits	Summer Squash	Misc. Melons
Fresh Tomatoes	Fresh Tomatoes	
Garlic	Garlic	
Grain	Hay Grain	
Lettuce	Head	Leaf, Misc. Greens
Onions	Dry Onions	
Other Truck	Bell Peppers	Celery, Other Vegetables
Pasture	Irrigated Pasture	
Processing Tomatoes	Processing Tomatoes	
Berries	Strawberries	Misc. Berries
Sweet Corn	Sweet Corn	
Vines	Wine Grapes	
Walnuts	Walnuts	

C.4.2. Geographic Regions

The Santa Clara County model has 3 geographic regions, including one in North County and two in South County. Regions are defined based on existing groundwater subbasins and management areas across the county – the Santa Clara Plain portion of the Santa Clara Subbasin, the Coyote Valley portion of the Santa Clara Subbasin, and the Llagas Subbasin.

Santa Clara Plain

The Santa Clara Plain is a large portion of the Santa Clara Subbasin and extends from the northern border of Santa Clara County to the Coyote Narrows. Total surface area, according the District's 2010 Urban Water Management Plan, is 225 square miles. The majority of streams and recharge facilities are located in this part of the county. Santa Clara Plain includes North County agriculture, which represents a small proportion of total county acreage.

Coyote Valley

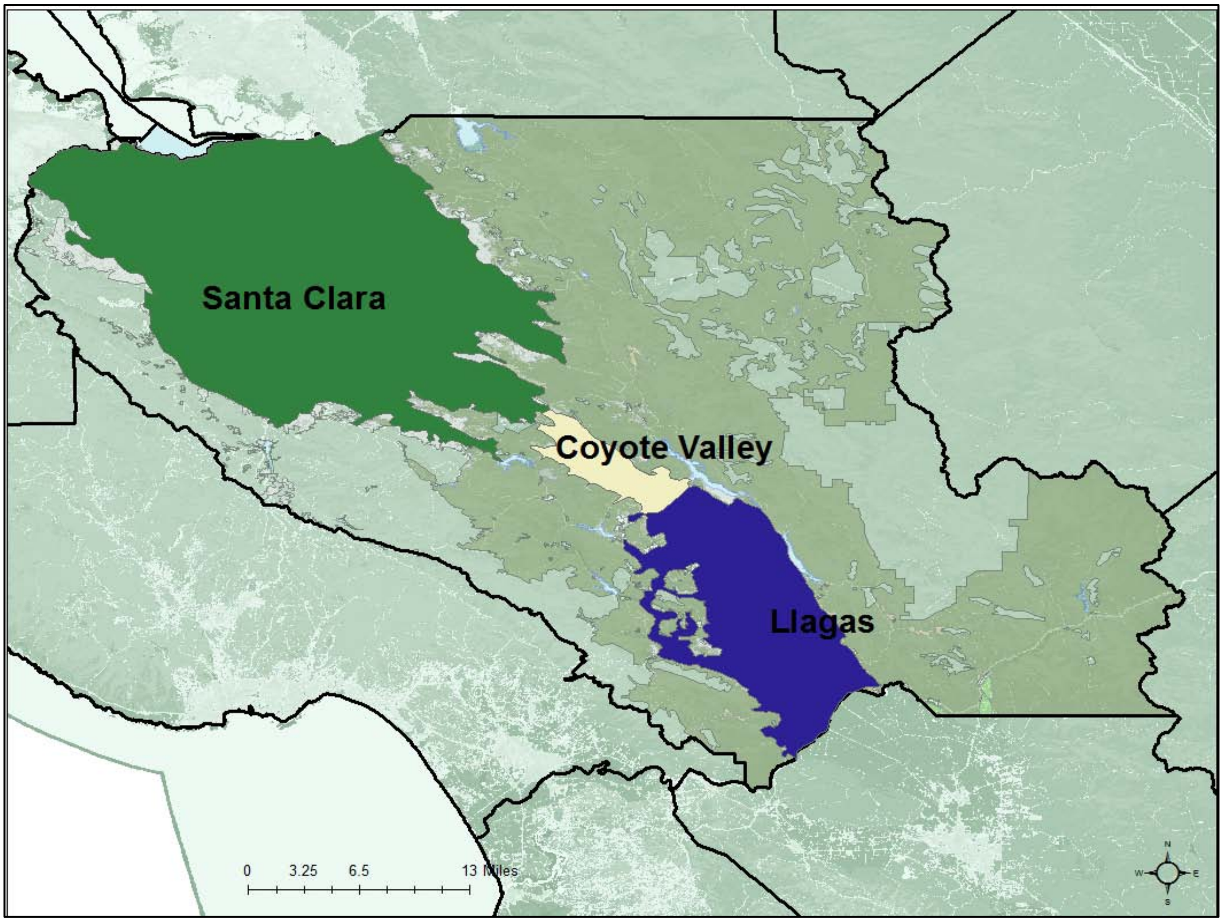
The Coyote Valley is a portion of the Santa Clara Subbasin which is hydraulically connected to the Santa Clara Plain, but treated as a separate unit by the District. The total surface area is 15 square miles. The Coyote Valley includes agriculture and land between San Jose and Morgan Hill.

Llagas Subbasin

The Llagas Subbasin lies to the south of Coyote Valley, extending for 15 miles. Agriculture in the basin includes high value and productive row crop land in the Morgan Hill, San Martin, and Gilroy areas.

Figure C1 illustrates the three geographical regions in the Santa Clara County model.

Figure C1. Santa Clara County Model Regions



C.4.3. Land Use Data

The Santa Clara model calibrates to a base year of observed land use, for each crop and region, based on the 2010 - 2011 county average. The years 2010 and 2011 are representative of average production conditions within the county and represent an ideal set of base years to calibrate against. These years included above average agricultural prices and normal rainfall conditions.

Land use data are compiled from three sources:

- Santa Clara County Agricultural Commissioner Annual Crop Reports
- Santa Clara County Pesticide Use Reports
- United States Department of Agriculture National Agricultural Statistics Service (NASS) Cropland Data Layers (GIS)

Agricultural Commissioner reports provide the most consistent source of land use information and are used as the benchmark standard in the model. The Agricultural Commissioner reports only include county-wide total crop acreages, therefore additional data are required to disaggregate land use for each of the subbasins.

Pesticide Use Reports are used to proportionally allocate crop acreage between each of the three groundwater areas. Pesticide Use Reports are subject to reporting and entry error in addition to double-counting error. These reports are consequently only used to disaggregate the total proportion of crops across the three groundwater areas. Absolute acreage is based on the Agricultural Commissioner reports.

NASS GIS layers are used to verify total crop acreage in each of the three groundwater areas. NASS uses satellite data and a classification algorithm in order to identify crop type (and other land use) down to a scale of 50 meters. The algorithm is very effective for regions where there is a relatively uniform crop mix, such as corn and soybeans in the Midwest, but is subject to classification error in regions such as California. As with the Pesticide Use Reports these data are only used to disaggregate land use by region.

Table C2 summarizes total harvested acreage in each of the groundwater areas, 2010 and 2011 average.

Table C2. Santa Clara County Model Crop Acreage, 2010-2011 Average

Crop Group	Santa Clara Plain	Coyote Valley	Llagas
Alfalfa	286	91	0
Apricot	105	41	76
Beans	6	390	437
Cherries	0	199	336
Citrus	118	13	100
Cucurbits	0	564	404
Fresh Tomatoes	0	26	732
Garlic	0	54	245
Grain	1,155	579	1,916
Lettuce	15	530	1,908
Onions	0	12	227
Other Truck	44	628	3,610
Pasture	85	22	361
Processing Tomatoes	0	21	1,014
Strawberries	0	19	76
Sweet Corn	21	392	753
Vines	657	324	559
Walnuts	29	24	111

C.4.4. Acreage Response Elasticities

An elasticity is the percent change in a variable, per unit of percent change in another variable or parameter. Acreage response elasticity is one component of supply response. It is the percentage change in acreage of a crop from a one percent change in that crop's price. Long run acreage response elasticities are used for this analysis. Acreage response elasticities are compiled from a study by economists at UC Davis using historical California data (Russo et al. 2012).

Elasticities are likely to vary between regions due to different production conditions. The calibration routine used for the Santa Clara County model allows individual region elasticities to vary from the aggregate measure. This more accurately reflects regional production conditions and allows the model to better reflect regional differences.

C.4.5. Crop Prices and Yields

Crop prices in the model correspond to 2010-2011 average prices received by growers in Santa Clara County. Data are compiled for each of the proxy crops and farm-gate prices are the same across all geographic regions.

Crop yields for each crop group in the Santa Clara model correspond to the proxy crops and are based on best management practices. Yields represent average expected yields under best management practices. Note that crop budgets, discussed in a subsequent section, also reflect best management practices. Thus, crop yields may be slightly higher than those estimated by calculating county averages, but are more consistent with the production costs.

Crop yield data are compiled from the University of California Cooperative Extension (UCCE) production cost budgets prepared by extension specialists and economists at the University of California at Davis (UC Davis). These data are validated using the Agricultural Commissioner Crop Reports, which include estimated county-average yields.

C.4.6. Other Input Costs

Input costs are derived from respective University of California Cooperative Extension (UCCE) crop budgets. These budgets are compiled for various years for each of the proxy crops. The most recent budget is used and dollar values are indexed to 2012 using the Gross Domestic Product (GDP) Implicit Price Deflator.

Confidential budgets provided by the Santa Clara County Farm Bureau were used to validate and, when necessary, adjust UCCE budgets to better reflect conditions in Santa Clara County.

C.4.7. Water Use, Availability and Costs

Irrigation water is available from three sources: surface water, recycled water, and groundwater. The primary source for agricultural irrigation water is groundwater. Water availability is reported in the District's 2010 Urban Water Management Plan and District reports available online.

Applied water per acre requirements for crops in the model are derived from California Department of Water Resources estimates. DWR estimates are based on geographic regions known as Detailed Analysis Units (DAU) and those regions in Santa Clara County are used for the model. Additionally, DWR data are checked against crop water requirements reported in the UCCE crop budgets.

The key source of irrigation water is groundwater pumping. Groundwater pumping costs, excluding the agricultural groundwater charge, are broken out into fixed, energy, and operations and maintenance (O&M) components in the model. Energy and O&M components are variable and the fixed component represents the amortized fixed cost of the well and pump over a standard useful life.

Pumping costs are calculated as two components, the fixed cost per acre foot based on typical well designs and costs within the county, plus the variable cost per acre foot. The variable cost per acre foot is O&M plus energy costs based on average total dynamic lift within the region.

Energy costs depend on the price of electricity. Energy cost is 21 cents per kilowatt-hour, which is an average of PG&E’s AG-1B and AG-4B rates. Overall well efficiency is assumed to be 70 percent.

The total dynamic lift (TDL) for each region is in feet, and includes both static lift and additional dynamic drawdown when pumps are operating. Base groundwater depth (static pumping lift) estimates are from data provided by the District which are converted to dynamic lift using the standard engineering formula.

C.5. Using the Model

Data and model organization are relatively streamlined given the complexity underlying the approach. The modeler needs only three files to run the model, although some expertise is required to adjust relevant parameters for policy simulations. The following three files are required:

- Excel workbook data input file
- Santa Clara County program file

- A small text file containing solver options

As with any model, some experience is required to understand the nuances of the modeling approach. The Santa Clara County model is written in the General Algebraic Modeling Software (GAMS) language. This is a standard language for economic models because the language is well-suited for the problem structure and the solvers are more robust than other competing model packages.

C.5.1. Data Input File

This is an Excel workbook that contains all of the data tables required for the model. Data are stored in a series of tabs where each tab corresponds to a specific input or parameter table. Some scalar parameters are incorporated into the model file itself rather than the data input file. Features of the data input file include the following.

- Disaggregated cost input data are stored on a separate tab in the data file. The workbook automatically aggregates the data, by region, input, and crop, for use in the Santa Clara County model.
- The input data file is automatically imported into the program file using the built-in GAMS program “xls2gms.” Thus the modeler can edit data within the excel file and it will be automatically updated in the model code.
- The data input file should be saved as “.xls,”

C.5.2. Model Program File

The program file (.gms) contains all of the model code. This includes a routine to automatically update input data, the three-step PMP calibration routine, and a series of models used for policy simulation. Simple or parameterized data input changes can also be made within the program file. The program file contains numerous comments and references. Also, calculations are included to double-check other calculations and to display intermediate results to assist model development.

C.5.3. Solver Options File

The solver options file (.op2) contains user-specified commands and definitions for the CONOPT-3 solver. The modeler may need to alter this file to change memory allocation, convergence tolerance, iterations, and to diagnose numerical convergence issues.

C.5.4. Output File

The Santa Clara program file will output a series of summary tables directly into Excel workbooks. It is generally up to the modeler to identify relevant parameters to export. For this analysis, changes in crop revenues, water use, and acreage were exported.

C.6. Relevant Studies Reviewed

Howitt, R.E. 1995. “Positive Mathematical Programming.” *American Journal of Agricultural Economics* 77 (2) 329-342.

Russo, C., Green, R., Howitt, R.E. 2012. “Estimation of Supply and Demand Elasticities of California Commodities." UC Davis Department of Agricultural and Resource Economics Working Paper No. 08-001.